Forest Landowners Guide to Tree Planting Success

PennState Extension

In many ways, planting trees is visionary.

Imagine a forest where there was once pasture, or woodland where there were once crops. Imagine a healthy, diverse forest, resistant to insects, fire, and disease, that will contribute to the property for generations. Planting trees has many benefits: improved wildlife habitat, high-quality trees for timber or specialty wood products, revegetated buffers along streams to protect water quality, increased species diversity and resiliency, enhanced attractiveness, and a more valuable estate for your family or heirs. Many view tree planting as an opportunity to leave behind a legacy—one that may benefit future generations, wildlife, and the environment. Whatever your purpose for planting trees, following the guidelines outlined in this publication can help you transform your land.

Most often, forests regenerate and old fields grow up in trees without our intervention. Sometimes the best plan is simply to monitor and support the natural growth of new trees. Some information in this publication can help you protect emerging and desired seedlings that have naturally occurred. However, planting trees can accelerate the natural progression or succession from field to forest or enrich a newly regenerating forest with an uncommon species.

Desired results are often evident in as little as 5 years following planting; the planted area will begin to transform into a forest. The most immediate benefits are food and cover for wildlife, soil erosion control, and improved water quality. Harvesting trees in a first thinning could begin as early as 15 to 20 years. It takes a dedicated landowner to plan decades ahead. Thankfully, many of us are, and our grandchildren and great grandchildren will benefit.

This publication focuses on the values and methods of establishing wooded areas on rural property. We'll begin with suggestions to help analyze the planting site and select appropriate tree species, then provide guidelines for preparing the site and the planting process, and finally, offer advice on maintaining and supporting the seedlings as they mature. Appendix A provides a calendar outlining steps for tree planting reforestation projects. Use this helpful calendar as a guide to the tasks you should consider before you start your project and how to follow up for success.

FIGURE 1
This old pasture was planted with a mixture of hardwood seedlings 4 years ago.
D. JACKSON
PENN STATE EXTENSION

Determining Planting Objective(s)

Determining objectives for planting is important because it will often dictate the species and number of seedlings needed. Objectives for planting are numerous and varied and include:

- Improving wildlife habitat-food and/or cover
- Producing future timber/investment
- Providing a privacy screen or windbreak
- Restoring a woodland
- Reintroducing a tree species
- Controlling erosion/improving water quality
- Reforesting an old field
- Special uses such as Christmas trees, sugarbush, nuts, or energy crops

Try answering the following questions to help you determine your objectives: What purpose(s) do you want the planting to serve? Why do you want to plant trees? With some thoughtful planning and decision making, the trees you plant will meet your objectives and provide numerous environmental benefits as well.

FIGURE 2 TOP LEFT
These Norway spruce were planted in a dense clump to provide wildlife cover.
D. JACKSON
PENN STATE EXTENSION

FIGURE 3 TOP RIGHT
These conifers were planted on an abandoned strip mine site. To alleviate compaction, the soil was ripped prior to planting. The site was also treated with an herbicide prior to planting to control competing vegetation.
S. SMITH
PENN STATE EXTENSION

FIGURE 4 BOTTOM
Sycamores, with their distinctive bark pattern, can be seen growing along streams and in bottom lands.
D. JACKSON
PENN STATE EXTENSION

Assessing the Planting Site

Not all tree species are suited to all sites. Observing and learning about the planting site a year or more before planting will provide useful insights. Consider the following:

- Soil type (drainage, fertility, and texture)
- Periodic flooding
- Amount of available sunlight
- Existing plant competition
- Exposure/aspect/orientation of the terrain (north and east slopes generally have better growing conditions, while south and west slopes are generally hotter and drier)

These site factors influence species selection. Some site conditions such as soil moisture, soil texture, and exposure are inherent to the site and not easily changed. It is important to select tree species that can thrive under given conditions. For example, aspen, black cherry, larch, red pine, and black walnut are shade-intolerant species. These trees will not tolerate even moderate levels of shade. If the site already has tree cover, shade-tolerant trees such as eastern hemlock, blackgum, red spruce, or sugar maple would be better choices.

Soil acidity or alkalinity (pH) is another key factor in determining which trees will grow best on a given site. Most tree species prefer neutral or slightly acidic soils. Also important is soil structure. Soils that are too tightly compacted will resist root

penetration, slow the passage of water and nutrients, and inhibit the free movement of oxygen and carbon dioxide. Hardwood (broadleaf deciduous) trees tend to grow best in loamy soils, a mixture of sand, silt, and clay. Many conifers do just fine in heavy clay or well-drained sandy soils and can tolerate dry southern exposures better than most hardwoods. As a rule, conifers can withstand adverse conditions better than hardwoods.

If a nearby but similar site already has trees, those trees may be a good indicator of existing site and soil conditions and what species may do well on your site. For example, speckled alder does well on moist, heavy clay; sugar maple prefers fertile, moderately well-drained soils; and American sycamore prospers in periodically flooded soils along stream banks and in bottom lands.

Another way to determine the soil type on your site is to consult the U.S. Department of Agriculture's Soil Survey Maps, which are available at your local conservation district office or online at **websoilsurvey.nrcs.usda.gov**. Soil samples can also be brought to your local Penn State Extension office where, for a nominal fee, they are sent out to assess soil fertility and pH. Contact your county extension office for details.

Primary factors that limit tree planting success

- Soil drainage: excessively drained or poorly drained
- Existing competing vegetation: grasses, weeds, and invasive plants
- Exposure/aspect: wind, sun, and shade
- Wildlife: deer, bear, voles, and other small mammals

Selecting Tree Species

The likelihood of project success greatly improves with clearly identified planting objectives and a selection of tree species that meet objectives and are compatible with site conditions. The goal is to plant the right trees in the right location. In other words, plant tree species that will meet objectives and grow well under the given site conditions.

The choice of tree species for planting in the northeastern hardwood region is extensive. There are dozens of species to choose from. Since tree planting is somewhat permanent, carefully consider your choices. Selecting a diversity of native species that have no major pest problems and are adapted to the site is important. The use of exotic species is discouraged today because many have become invasive and now cause damage to native plant and animal communities. Because choosing the best tree species for a particular site is so important, consider seeking advice from a knowledgeable natural resource professional or forester before ordering.

Planting Density and Arrangement

Determining an appropriate spacing between trees is necessary when developing a planting design. In general, plant trees at a closer spacing for quality hardwood production. This encourages straight boles and small lower branches that self-prune at an earlier age. Plantings for wildlife use wider spacings, up to 20 feet, to encourage crown development and earlier seed production. When determining spacing, consider the tree's crown width when it reaches a useful size. For example, when growing trees for timber, allocate space so individual trees are just beginning to crowd one another when they are large enough to support a commercial firewood or pulpwood thinning, generally an 8- to 10-foot spacing. Higher densities will require thinning at an earlier age to remove excess trees and reduce competition.

Planting arrangement refers to the pattern or distribution of tree and shrub species across a planting site. For example, a mixed hardwood plantation may concentrate black walnut seedlings on the deeper soils of the lower slope and plant red and white oak seedlings on hill tops and convex-shaped slopes.

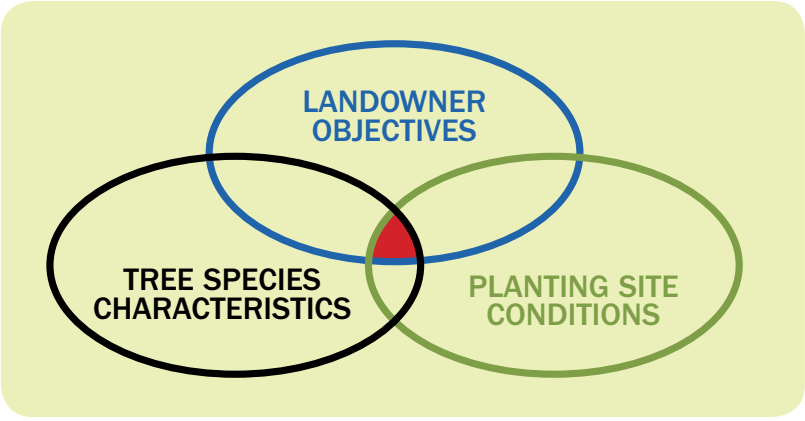


FIGURE 5
For a planting project to be successful, find the overlap among site conditions, ownership objectives, and characteristics of desired species. Some projects have more overlap and thus more choices for species selection.
P. SMALLIDGE
CORNELL COOPERATIVE EXTENSION

TABLE 1 | *Tree selection table.*

Tree selection tables cross-reference the primary reason for planting with soil and site conditions to compile a list of possible tree species.

Tree species	Site			Use				Deer browse tolerant	Insect/ disease tolerant	Shade tolerant
	Wet (hydric)	Moist (mesic)	Dry (xeric)	Windbreak/ screen	Timber/ lumber	Wildlife	Stream bank/ riparian buffer			
Conifers										
Eastern red cedar *(Juniperus virginiana)*	P	G	G	G	P	G	P	F	G	P
American larch *(Larix laricina)*	G	G	G	F	P	F	F	G	G	P
Norway spruce *(Picea abies)**	G	G	F	G	P	G	F	G	G	F
White spruce *(Picea glauca)*	G	G	F	G	P	G	P	G	G	F
Red spruce *(Picea rubens)*	G	G	G	G	P	G	G	G	G	G
Red pine *(Pinus resinosa)*	P	G	G	P	P	F	P	G	F	P
Pitch pine *(Pinus rigida)*	F	F	G	P	F	F	P	G	F	P
White pine *(Pinus strobus)*	F	G	G	G	F	G	F	F	F	F
Scotch pine *(Pinus sylvestris)**	P	G	G	P	P	F	P	G	P	P
Virginia pine *(Pinus virginiana)*	P	G	F	P	P	F	F	F	F	P
Northern white-cedar *(Thuja occidentalis)*	G	G	F	G	P	G	G	P	G	G
Eastern hemlock *(Tsuga canadensis)*	G	G	P	G	F	G	G	P	P	G
Hardwoods										
Box elder *(Acer negundo)*	G	G	F	F	P	F	G	F	G	G
Red maple *(Acer rubrum)*	G	G	F	P	F	P	G	F	G	G
Silver maple *(Acer saccharinum)*	G	G	P	F	F	F	G	P	G	G
Sugar maple *(Acer saccharum)*	P	G	F	P	G	G	F	P	G	G
Buckeyes *(Aesculus* spp.*)*	F	G	P	P	P	P	G	G	G	G
Serviceberries *(Amelanchier* spp.*)*	P	G	F	P	P	G	G	F	G	G
Yellow birch *(Betula alleghaniensis)*	F	G	P	P	G	F	P	F	G	F
Black birch *(Betula lenta)*	P	G	F	P	F	P	F	G	G	P
River birch *(Betula nigra)*	G	F	P	P	P	F	G	G	G	P
Paper birch *(Betula papyrifera)*	F	G	G	F	P	F	F	G	P	F
Hickory *(Carya* spp.*)*	P	G	F	P	F	G	F	F	G	F
American chestnut *(Castanea dentata)*	P	G	G	P	G	G	F	P	P	F
Hackberry *(Celtis occidentalis)*	P	G	G	F	P	G	G	F	G	F
Eastern redbud *(Cercis canadensis)*	P	G	F	P	P	F	G	F	G	G
Flowering dogwood *(Cornus florida)*	P	G	F	P	P	G	F	P	P	G
Hawthorn *(Crataegus* spp.*)*	F	G	G	F	P	G	F	P	G	P
American beech *(Fagus grandifolia)*	F	G	P	P	F	G	F	G	P	G
White ash *(Fraxinus americana)*	P	G	P	P	G	P	G	P	P	F
Green ash *(Fraxinus pennsylvanica)*	G	G	F	P	F	P	G	F	P	F
Butternut *(Juglans cinerea)*	P	G	G	P	F	F	G	F	P	P
Black walnut *(Juglans nigra)*	P	G	P	P	G	G	G	G	F	P
Yellow poplar *(Liriodendron tulipifera)*	P	G	F	P	G	P	F	P	G	P
Cucumbertree *(Magnolia acuminata)*	P	G	P	P	F	F	G	P	G	P
Blackgum *(Nyssa sylvatica)*	G	G	F	P	P	F	G	P	G	G
Sycamore *(Platanus occidentalis)*	G	G	F	P	P	F	G	F	G	F
Eastern cottonwood *(Populus deltoides)*	G	G	F	G	P	F	G	F	G	P
Bigtooth aspen *(Populus grandidentata)*	F	G	G	P	P	G	G	G	F	P
Quaking aspen *(Populus tremuloides)*	F	G	G	P	P	G	G	G	F	P
Black cherry *(Prunus serotina)*	P	G	G	P	G	G	F	G	G	P
White oak *(Quercus alba)*	P	G	G	P	G	G	F	P	F	F
Swamp white oak *(Quercus bicolor)*	G	G	P	P	F	G	G	P	F	F
Chestnut oak *(Quercus montana)*	P	G	G	P	G	G	P	F	F	F
Pin oak *(Quercus palustris)*	G	G	F	P	P	G	G	P	F	P
Northern red oak *(Quercus rubra)*	P	G	G	P	G	G	F	P	F	F
Black locust *(Robinia pseudoacacia)*	F	G	G	G	F	F	G	F	P	P
Black willow *(Salix nigra)*	G	F	P	F	P	F	G	P	G	P
Sassafras *(Sassafras albidum)*	P	G	F	P	P	G	F	F	G	P
Basswood *(Tilia americana)*	P	G	F	P	G	F	F	P	G	G
American elm *(Ulmus americana)*	G	G	F	P	P	P	G	F	P	F
Slippery elm *(Ulmus rubra)*	F	G	P	P	P	P	G	F	P	G

*Nonnative species.

G = good; F = fair; P = poor.

Source: Revised from "Northeastern Tree Planting and Reforestation" (Cornell University Cooperative Extension).

Sycamore and red maple will do better on the wetter sites. Planting a diversity of species will ensure the site is less prone to attack by insects and diseases. The planting will also provide a diverse habitat for wildlife. Mixing conifers (e.g., white pine) and hardwoods on a site is recommended. The benefits of these mixtures include earlier crown closure, reduced cost over pure hardwood plantings, wind protection, and improved hardwood quality as conifers force hardwoods to grow straight and self-prune lower branches earlier.

TABLE 2 | *Spacing by trees per acre.*

Spacing (feet)	Trees per acre
4 by 4	2,723
5 by 5	1,742
6 by 6	1,210
7 by 7	889
8 by 8	681
9 by 9	538
10 by 10	436
11 by 11	360
12 by 12	303

To calculate numbers of trees per acre, multiply the planned spacing (in feet) within rows by the spacing (in feet) between rows and divide that number into 43,560, the number of square feet in an acre.

Ordering Seedlings

After gathering information about the site, the best tree species, the number of seedlings needed, and the planned layout, it is time to order seedlings. Plan to order trees in the fall or winter so they can be shipped or picked up in the spring. Ordering trees grown from seeds collected from the region where you will be planting is preferred. These trees are better adapted to local soil and weather conditions and will likely have a higher survival rate. State forestry and wildlife agency nurseries, county conservation districts, and private nurseries are possible sources of tree seedlings. A rule of thumb is to avoid ordering from nurseries more than 100 miles south and west of the state line.

Essentially, two types of seedlings are used in large planting projects, bare-root and containerized. Bare-root seedlings are the most common since they are economical and easy to handle. Nurseries grow bare-root seedlings in nursery beds, lift them during the dormant season, and bundle them without soil. They are stored in refrigeration units so they remain dormant until shipped. They are described using two numbers, such as 1-0, 2-0, or 2-1 stock. The first number refers to how many years the seedlings grew in the original nursery seedbed, and the second refers to how many years they grew in a transplant bed. Transplants generally cost more, but they may be more resilient to transplanting stress. Seedlings should have a balanced 1:1 shoot-to-root ratio. Those with large shoots in comparison to roots may be prone to dieback.

Containerized seedlings, or tublings, are usually grown in a greenhouse in containers between 1 and 2 inches in diameter. These containers are either plastic or biodegradable; with plastic containers, it is necessary to remove the container prior to planting. Containerized seedlings offer the advantage of less transplant shock and are useful for planting on dry sites or for planting later into the growing season. A third alternative is to purchase potted or balled and burlapped trees. These are quite expensive, difficult to handle, and not recommended for large-scale plantings.

TABLE 3 | *Wildlife benefits of common trees and shrubs.*

Plant type	Species	Wildlife benefits
Evergreens/ conifers	White pine	Winter cover for songbirds, deer, and other wildlife
	Eastern hemlock	Nest sites for mourning doves and many songbirds
	Spruce	Food for red squirrels and many other songbirds
	Red cedar	
	White cedar	
Nut trees	Oak	Food for songbirds, chipmunks, squirrels, deer,
	Hickory	wild turkey, bears, and many other species
	Beech	
	Walnut	
Fruiting trees	Black cherry	Food for songbirds, fox, deer, wild turkey, and bear
	Serviceberry	Nesting sites for cardinals and many other songbirds
	Flowering dogwood	
	Hawthorn	
	Blackgum	
	Hackberry	

Source: Revised from 4-H project book *The Wildlife Manager* (Penn State Extension).

Preparing the Site

Proper site preparation is essential for planting success. It is especially critical when planting hardwoods. Lack of site preparation is a leading cause of seedling mortality. Controlling weeds, grasses, undesirable brush, and invasive plants prior to planting is necessary. Soil conditions will make little difference if the young tree receives little water or sunlight and has no room to grow. Ideal conditions for seedlings are often ideal for weeds and other plants that compete for sunlight and water. Site preparation often involves mechanical or chemical treatments or a combination of the two. Most site preparation is done the season prior to planting. Therefore, planning ahead is essential.

Preparing Old Field Sites

For old field sites, a combination of mowing and herbicide or herbicide and disking treatments are most effective. Herbicide treatments can include broadcast, spot, or row applications in the late summer or fall prior to planting. Sites are most commonly mowed in mid-August and then treated with a broad-spectrum herbicide such as glyphosate (e.g., Rodeo and Roundup) and/or a preemergent herbicide such as sulfometuron-methyl (e.g., Oust XP and Spyder) a few weeks later. Mowing encourages a flush of new growth, thus increasing herbicide effectiveness. If making spot herbicide applications, it is a good idea to mark your planting spots with flags or stakes as they may not be obvious in the early spring, when most grasses and weeds are brown.

FIGURE 6 TOP
This photo depicts potted, containerized seedlings, or tublings, and "bare-root" seedlings. Because bare-root seedlings are economical and easy to handle, they are most commonly used for large planting projects. However, they are the least flexible of all planting stock and must be planted when seedlings are dormant.
D. JACKSON
PENN STATE EXTENSION

FIGURE 7 MIDDLE
Stem cuttings, such as this shrub willow, are used to establish willow and poplar plantings. They are inexpensive and often used to establish stream protection plantings and short-rotation woody crop plantations.
D. JACKSON
PENN STATE EXTENSION

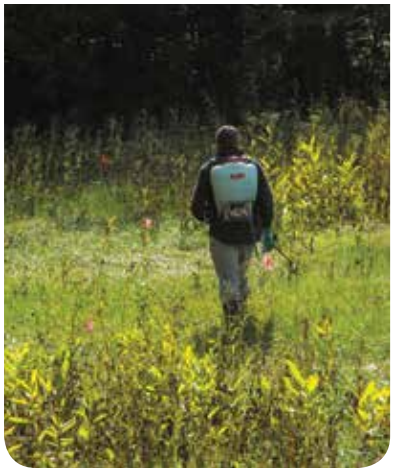


FIGURE 8 BOTTOM LEFT
Sod-forming grasses, like tall fescue, can rob trees of moisture and nutrients. In this photo, the row of trees on the far right received no site preparation treatment. To the left, the sod was sprayed with a glyphosate herbicide prior to planting.
D. JACKSON
PENN STATE EXTENSION

FIGURE 9 BOTTOM RIGHT
Using a backpack sprayer to spot-treat competing weeds and grasses in the fall prior to planting is an effective way to prepare planting sites. Marking spots with flags or stakes will ensure seedlings are planted in treated locations come spring.
P. PANNILL
U.S. FISH AND WILDLIFE SERVICE

In most cases, mowing or disking alone is insufficient for controlling severe weed competition, except in recently row-cropped sites. These sites generally need little or no site preparation, especially if the crop was harvested the fall prior to planting. If soil is compacted, light disking prior to planting may be necessary and can increase seedling survival. Allow time for soil to settle before planting.

Preparing Existing Timber Stands

Generally, carefully designed and implemented silvicultural prescriptions will lead to naturally regenerated hardwood stands in Pennsylvania and across the Northeast. However, there are instances when enrichment plantings are necessary and desirable. Enrichment plantings may be used to introduce genetically improved varieties, such as American chestnut, or species that are difficult to regenerate, such as oak. Landowners may also wish to introduce native tree species that provide food and cover for wildlife.

Tree planting in existing timber stands is generally more successful when it occurs in openings created by timber harvests or natural tree mortality rather than under an existing canopy. Planting success in these "regeneration openings" can be improved by cutting and using an herbicide to control any undesirable herbaceous vegetation, trees, and shrubs prior to planting. Herbicide applications are effective at controlling competing grasses and ferns as well as sprouting from freshly cut stumps of undesirable trees and brush.

Herbicides

Properly applied, herbicides provide a safe and effective way to eliminate weeds, grasses, and brush that compete with seedlings for sunlight and water. Fall herbicide applications are a common site preparation treatment prior to planting. Summer herbicide applications are recommended annually following planting until trees are well established, possibly for up to 5 years (see Postplanting Maintenance section).

When choosing an herbicide, consider the targeted weed(s) and application method that best protects desirable plants, the user, and the environment. Apply preemergent herbicides before weeds appear. Use postemergent herbicides to control already established weeds and other vegetation.

When mixing and applying herbicides, wear appropriate protective clothing (see product label) such as rubber gloves, rubber boots, long-sleeved shirt, and eye protection. Apply herbicides to dry foliage so spray will adhere well. Wind speeds of less than 10 mph reduce chemical drift onto desirable seedlings or nearby plants. See the Penn State Extension Forest Vegetation Management website at **extension.psu.edu/fvm** for herbicide application methods and products.

FIGURE 10 TOP LEFT
A skid steer with tracks and brush hog deck mounted on the front is used to mow overgrown old field sites prior to planting. Follow-up herbicide treatments will still be necessary to control competing and invasive plants that resprout.
D. JACKSON
PENN STATE EXTENSION

FIGURE 11 TOP RIGHT
This striped maple was cut and stump treated with a herbicide containing triclopyr to prevent it from resprouting and competing with planted seedlings.
D. JACKSON
PENN STATE EXTENSION

FIGURE 12 MIDDLE
This site was prepared by first applying a glyphosate herbicide and then lightly disking a few weeks later.
D. JACKSON
PENN STATE EXTENSION

FIGURE 13 BOTTOM
This regeneration opening was prepared for planting by felling residual "cull" trees. The seedlings were placed in tree shelters to protect seedlings from deer browse and allow for spot herbicide applications to control competing vegetation.
D. JACKSON
PENN STATE EXTENSION

Seedling Care and Handling

Plant seedlings soon after they arrive, preferably within 24 hours and no more than one week. Store them in a cool, damp environment in the original packaging, protected from freezing. Stack bundles loosely to provide ventilation. Keep roots moist by adding a small amount of water to the open end of the bundles, and do not handle seedlings until you are ready to plant.

When transporting, take care to protect seedlings from exposure to wind and direct sunlight. Do not transport seedlings in the bed of a truck unless it is a cool, cloudy day or they are covered with a tarp. Be careful not to damage stems and buds. Buds are the source of new growth, which the tree will need to get established. At the planting site, keep extra seedlings wrapped tightly in their original packaging, covered with a reflective tarp, and stored in the shade. Only remove from storage what can be planted that day.

When to Plant

In Pennsylvania, the best time to plant is between early March and early May. Plant once frost leaves the ground and prior to bud break, when seedlings are dormant. It is essential to plant bare-root seedlings before buds begin to swell and new growth starts to emerge. Plant as early in the spring as possible, when there is high soil moisture and cool temperatures. This will help ensure root establishment before the hotter, drier summer months. Trees planted after mid-May might not survive summer's intense heat and water stress. Planting in the fall may expose trees to severe winds and cold temperatures, which can desiccate seedlings, as well as frost heaving when the ground freezes and thaws. Calm, cool, and overcast days are best for tree planting. Under these conditions, roots are less likely to dry out before getting them in the ground.

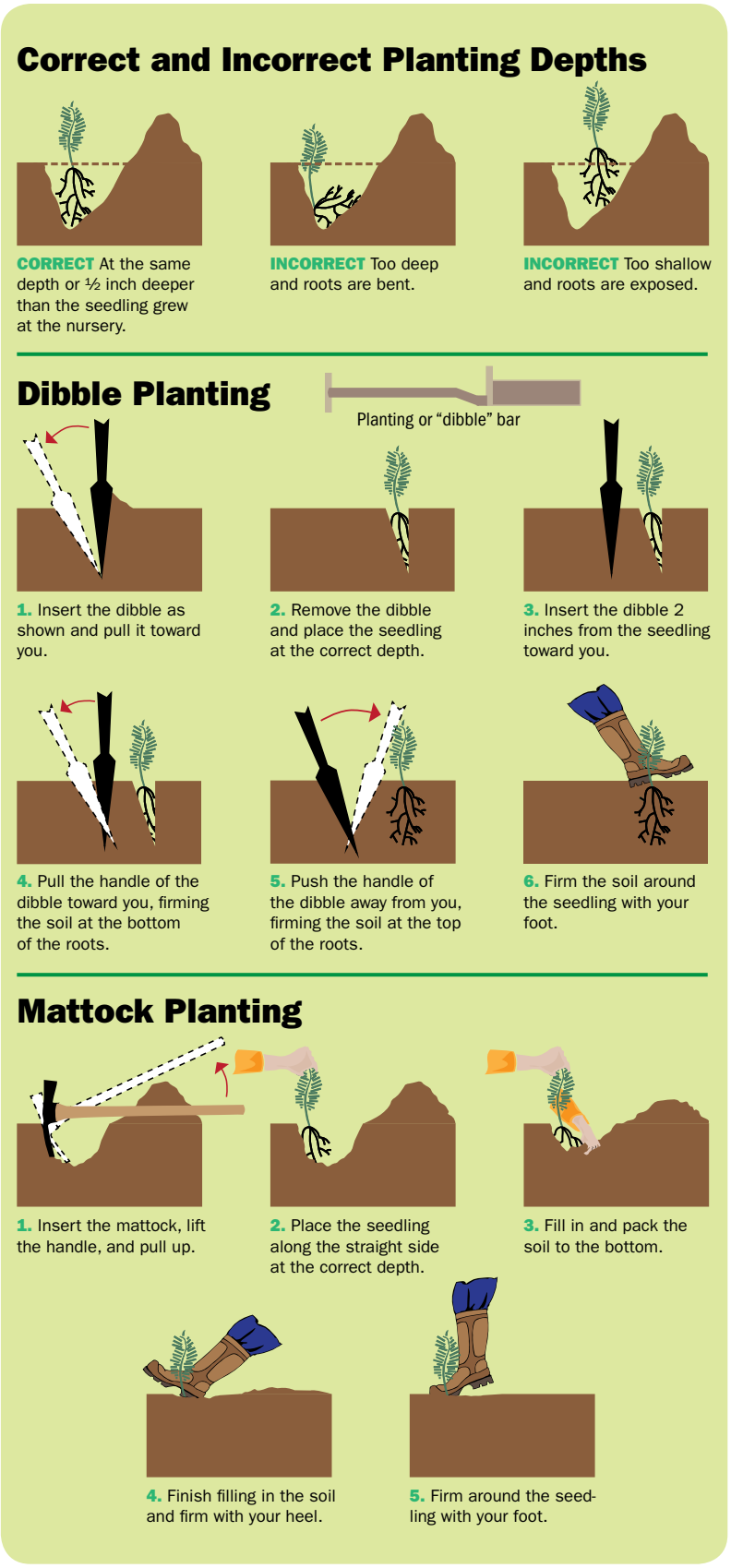
Planting Seedlings

1. Seedling roots should be kept moist and cool at all times by carrying them in a bucket of muddy water or planting bag with wet towels, peat moss, or burlap. Roots may also be covered with one of the hydrophilic gels or moisture enhancers. Never carry bundles of seedlings in your hand exposed to the air or completely immersed in a bucket of water for extended periods of time.
2. Dig a hole with a planting shovel, mattock, or auger. If using a planting bar (see Fig. 15), work the blade vertically into soil, first pushing the handle away and then pulling it toward you to open a planting hole. It needs to be deep enough to accommodate roots vertically.
3. Set the seedling at the same depth it grew in nursery, only as deep as the root collar. Roots should be straight, not balled or twisted. Long lateral roots can be pruned to aid in planting.
4. Hold the tree straight while the planting hole is backfilled. If using a planting bar, push the blade into the soil just behind the planting hole; pull the handle toward you to close the bottom of the hole, and push it forward toward the seedling to close the top.
5. Gently pack soil around roots using your hands or the heel of your boot. This will eliminate air pockets, which can desiccate roots. To test whether a seedling is planted properly, give it a firm but gentle tug. It should remain firmly planted.

FIGURE 14A TOP
Plant seedlings to the same depth they grew in the nursery. Look for the root collar as pointed out in this image and plant to that depth.
G. GILMORE
PENN STATE EXTENSION

FIGURE 14B BOTTOM
While planting, keep seedling roots moist by carrying them in a bucket of muddy water.
D. JACKSON
PENN STATE EXTENSION

FIGURE 15
These three diagrams illustrate correct and incorrect planting depths, how to use a planting bar or dibble to plant seedlings, and how to use a mattock to plant seedlings.
SOURCE: REVISED FROM "HOW TO PLANT A TREE" (THE GREEN WORLD PROJECT)



Augers

Augers are another useful tool for planting trees. They can be mounted on a tractor or skid steer or handheld and powered by two-cycle engines and are used on steep, rocky soil and where logging debris may be present. There are a couple of pitfalls when using this type of equipment. In clay soils, the sides of the hole can become "glazed," preventing tree roots from growing beyond the loose soil in the backfill. Another common problem is losing backfill material in debris that surrounds the planting hole. Prevent this by first scalping grass, leaves, and other debris away from the hole before augering. Be sure to properly pack soil back into the planting hole to prevent later settling. Settling can also be minimized by augering the hole only as deep as necessary to accommodate the tree roots.

Machine Planting

Machine planting expedites large-scale operations, such as establishing a plantation in a large, open field. Machine planting is not suited for planting in woods or on rocky or steep terrain. Two people are necessary for this job: one to drive the tractor and one to ride on the planter. The planting machine creates an opening or slit in the soil, and the person riding in the tree planter places a seedling in the soil at regular intervals. The angled rear wheels of the planting machine finish the job by closing the hole and packing soil. When conditions are right, planting thousands of seedlings in a single day is possible.

Protection

Protecting seedlings once they're in the ground is one of the most important aspects of any successful planting project. A common recommendation to protect your investment is to use tree shelters, also called tree protectors or tree tubes. Shelters shield seedlings from harsh weather, animal predation, mowers, and herbicide spray. They provide increased protection from deer and rodents, provide a better growing site by reducing wind and increasing humidity, and make follow-up herbicide applications faster and easier by shielding seedlings from spray.

Tree shelters are designed for hardwood seedlings. Most conifer species do not thrive in tree shelters. Tree shelters are expensive and may not be economical for large projects. If deer browsing is a problem, an 8-foot woven-wire fence erected around the entire project area may be more cost effective. The cost of tree shelters should include a support stake and bird netting to cover the top of shelters. Without netting, birds may enter the tubes in search of nesting sites and become trapped. Most tree shelter manufacturers provide instructions for assembly and installation. Stakes are generally purchased separately. Use something durable, such as oak, locust, or treated pine, that will last for a number of years.

Deer

In areas with high deer impact, browsing on newly planted tree seedlings is a real concern. Deer can devastate a planting project, causing tree mortality and deformed seedlings. As seedlings grow into sapling size

FIGURE 16 TOP
Some common tree planting tools include a tree planting bag, KBC bar, dibble bar, mattock, and auger. An auger works well for planting hardwood seedlings with relatively large root systems. A hoedad (inset), similar to a mattock, is another tree planting tool commonly used when planting large quantities of conifers.
D. JACKSON
PENN STATE EXTENSION

FIGURE 17 MIDDLE
Tractor-pulled tree planting machines work well when planting conifers in large, open fields and allow thousands of trees to be planted in a single day with little effort.
H. WEBSTER
PENN STATE DUBOIS, RETIRED

FIGURE 18 BOTTIOM
Tree shelters provide a "greenhouse effect" by reducing wind and increasing humidity. They also protect seedlings from deer and rodents and make herbicide applications faster and easier by shielding seedlings from spray.
D. JACKSON
PENN STATE EXTENSION

(1–5 inches in diameter at breast height), bucks rubbing their antlers can also be an issue. Tree shelters at least 4.5 feet tall will minimize deer browsing impact. To deter buck rubbing, keep shelters in place as long as possible, until tree is nearly the diameter of the tube. Another alternative is to cage trees with woven-wire or plastic mesh fencing.

Voles

Voles are small mouselike rodents, and they can be quite numerous in old fields and pastures. Voles can damage and kill trees as large as 3–4 inches in diameter by gnawing on roots and girdling stems. They are a leading cause of failures in tree planting projects. To protect seedlings from voles, use a shelter at least 12–18 inches in height secured tightly to the ground with a stake. Periodically inspect shelters, tapping them tight to ground. This is particularly important in spring, following winter frost heaving soil that lifts shelters and stakes. Weed control around seedlings using herbicides is another key to avoiding vole damage. Controlling weeds and grasses around seedlings discourages voles by removing their protective cover. Mowing the entire planting area in old fields with severe vole problems is also an option.

Bears

Sometimes bears will destroy your planting investment. Bears are curious animals. Some people speculate that bears view tree shelters as toys. Others have suggested that bears destroy tree shelters in search of wasp larvae, as wasps often build nests inside the tube. Short shelters, 18–24 inches in height, may attract fewer wasps than traditional 4-foot shelters and therefore may help avoid bear damage. However, these short tubes do not protect seedling from deer browsing. In areas where seedlings require protection from deer, consider using woven-wire fence or plastic mesh. Cut fencing or mesh to length and form it into 1- to 2-foot-diameter circles to place around seedlings.

FIGURE 19 TOP LEFT
In areas with high deer impact, a 4-foot-tall tree shelter is inadequate at protecting tree seedlings from browsing. This red oak seedling was browsed heavily as soon as it emerged from the top of the shelter.
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FIGURE 20 TOP MIDDLE
Voles will tunnel beneath tree shelters to nest and gnaw on tree roots and stems. Control weeds and grasses around seedlings and push or tap shelters back down in early spring following winter frost heaving.
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FIGURE 21 TOP RIGHT
Rodent gnawing damage.
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FIGURE 21 BOTTOM
Bears can damage planting projects. Some speculate that they view shelters as toys or that they are possibly looking for a meal of wasp larvae.
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Postplanting Maintenance

Do not expect to walk away from seedlings once they are in the ground. Periodic inspections are necessary several times each year for the first 4–5 years to discover and address problems and ensure seedlings are holding their own against the environment. Maintenance includes controlling weed competition using either mulch or herbicides, repairing or replacing damaged tree shelters and broken stakes, and pruning trees to maintain proper tree form. During inspection, be sure to bring extra shel-

ters, ties, stakes, a hammer, and pruning shears.

Checking and maintaining tree shelters is essential; you may find shelters damaged or destroyed by curious bears, wind, snow, or ice, or leaning as a result of broken ties or rotted stakes. Broken stakes can topple trees, pinning and killing them. This also allows rodents easy access to the seedling. As trees approach the top of the tube, remove bird netting. If not removed, growing shoots can become intertwined in netting, causing new growth to curl or "pigtail." As the tree diameter reaches that of the shelter, remove the shelter to protect the young trunk from possible girdling. Many shelters claim to "break down" or biodegrade from sun exposure over a period of years. However, it is always important to check and make sure the shelter is not restricting tree diameter growth.

FIGURE 22 TOP
Correct for tree form by pruning out double leaders when trees are young. Also, removing lower branches as the tree grows in height will improve tree quality and encourage height growth.
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FIGURE 23 BOTTOM LEFT
A better alternative to mowing planted areas to control weeds is to spot-treat around individual trees with a broad-spectrum herbicide.
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FIGURE 24 BOTTOM MIDDLE
FIGURE 25 BOTTOM RIGHT
Organic mulches [24] and commercial weed barrier fabric [25] can provide some level of weed control around planted trees.
[24] **H. WEBSTER**
PENN STATE DUBOIS, RETIRED
[25] **D. JACKSON**
PENN STATE EXTENSION

Weed Control

Controlling weed competition around individual seedlings is one of the most important maintenance practices performed during the first 3–5 years. Controlling weed competition will reduce vole damage, provide greater air circulation, and increase the amount of sunlight, nutrients, and water available for newly planted trees. Many old field plantings require the application of a broad-spectrum herbicide such as glyphosate (e.g., Rodeo and Roundup) at least twice annually to control competing vegetation around shelters. When using an herbicide, apply it to a 3- to 4-foot-diameter spot around each tree, being careful not to get spray onto seedling foliage. Tree shelters work well at protecting seedlings from herbicide spray. If significant grass and weed growth is trapped inside the shelter, simply slide the shelter up and pull or carefully spray this vegetation.

Mowing

Unless there is a severe small rodent problem, mowing the entire planting area is not recommended and should be avoided whenever possible. Mowing does not eliminate the roots of vegetation competing for water and nutrients. Mowing may damage seedlings, cause soil compaction, and favor the establishment of grasses that are severe competitors to tree seedlings.

By avoiding such mowing, some natural tree seedling regeneration may occur between planted

trees, giving the site a more natural appearance. Also, mowing destroys beneficial wildlife habitat and prevents natural succession of the site from occurring, thus slowing the reforestation process. However, you may find it necessary to control undesirable and invasive tree and brush species that commonly invade old field sites and disturbed woodlands by mowing, pulling, or spraying.

Conclusion

Even when planned carefully and all necessary precautions are taken, 10–20 percent seedling mortality is not unusual. Replacement planting in successive years can help recoup losses. A successful planting comes from a combination of good timing, good luck, hard work, and knowledge of the planting site and tree species. This publication provides an overview of options, but it can't cover detailed advice about specific situations. For that, consult a natural resource professional. With proper planning and implementation, your tree planting project will be successful.

Resources

Publications

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Pijut, Paula M., "Planting and Care of Fine Hardwood Seedlings: Planting Hardwood Seedlings in the Central Hardwood Region" (West Lafayette: Purdue University Hardwood Tree Improvement and Regeneration Center, 2008), **https://www.extension.purdue.edu/extmedia/fnr/fnr-210.pdf**.

Wise, D., et al., *Landowner Guide to Buffer Success* (Harrisburg: Chesapeake Bay Foundation, 2007), **www.cbf.org/Document.Doc?id=257**.

Webinar

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Websites

Nursery Industry Business Directory, Find Nurseries.Com: **www.findnurseries.com**

Penn State Extension Forest Vegetation Management: **extension.psu.edu/fvm**

Plant Native: **www.plantnative.com**

FIGURE 26
Natural tree seedling regeneration will be encouraged by not mowing between planted trees. Naturally occurring seedlings, like the walnut shown here, give the site a more natural appearance and speed up reforestation.
D. JACKSON
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Appendix A: Tree Planting Project Calendar—Steps to Tree Planting Success

Year Prior to Planting

April and May
- Review and identify planting objectives.
- Investigate whether government cost-share programs are available.
- Request tree seedling flyers from nurseries.

May through June
- Walk site with natural resource professional.
- Assess soil moisture and competing vegetation.

August through December
- Prepare site—treat competing vegetation.
- Calculate acres, lay out spacing, determine number of seedlings needed for each species.

Year of Planting

January through March
- Place tree seedling order; note delivery date.
- Schedule time and planting assistance.

March through April
- Receive trees and plant immediately.
- Install tree seedling protection/shelters.

June through October
- Inspect seedlings monthly; maintain protectors.
- Monitor competing vegetation and treat with herbicide as necessary.

Year Following Planting

February through March
- Check tree seedling protectors/shelters.
  - Fix or replace any downed, damaged, or leaning protectors.
  - Replace broken or rotten stakes.
  - Remove any wasp nests.
- Assess survival and mark any missing or dead trees.

April through May
- Replant if necessary.

May through June and August through September
- Herbicide competing vegetation as necessary (two applications may be necessary each year).

Years 2 through 5 Following Planting

February through March
- Maintain tree protectors/shelters and stakes.
- Prune as necessary to promote correct form.
  - Remove any double leaders.
  - Slowly prune lower branches to promote clear stems.

May through June and August through September
- Herbicide competing vegetation as necessary.
- Remove protectors/shelters once tree begins to reach shelter diameter; consider the risks when removing shelters.

Forest Landowners Guide to Tree Planting Success

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Cover photos by David Jackson (lower left and top right), Katie Mann (lower right), and Brian Salvato (top left).

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