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A guide to RIPARIAN TREE AND SHRUB PLANTING *in the Willamette Valley: Steps to Success*

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Contents

Figure 1. Newly installed planting along Newton creek, Benton County, Oregon.

Photo by Donna Schmitz, Benton Soil and Water Conservation District.

Planting trees and shrubs to restore streamside areas, enhance fish and wildlife habitat, improve water quality, and achieve other environmental benefits is increasingly common in Oregon (figure 1). But the success of riparian plantings varies widely, and some fail outright (see "Survey shows variable success with riparian tree planting," page 2).

Establishing a riparian planting is not easy. Seedling survival and growth are often poor. Competition from weeds can be high. Animal damage is common. Soil texture on a site can vary from coarse sand to dense clay. Planting sites may flood frequently in winter yet become very dry each summer. Management tools such as irrigation, machinery, and herbicides may be regulated or restricted. Particular challenges in the Willamette Valley include summers that are hotter and drier than in the adjacent Coast Range and Cascades foothills and streams that run through highly modified agricultural and urban areas (figure 2).

This guide describes six steps to help landowners, watershed council members, agency personnel, and others communicate about, plan, and implement successful riparian tree and shrub plantings in the Willamette Valley:

1. Plan your project.
2. Select and obtain plant materials.
3. Prepare the site.
4. Plant your trees right.
5. Take care of the planting.
6. Monitor and learn from results.

Oregon State University Extension Service

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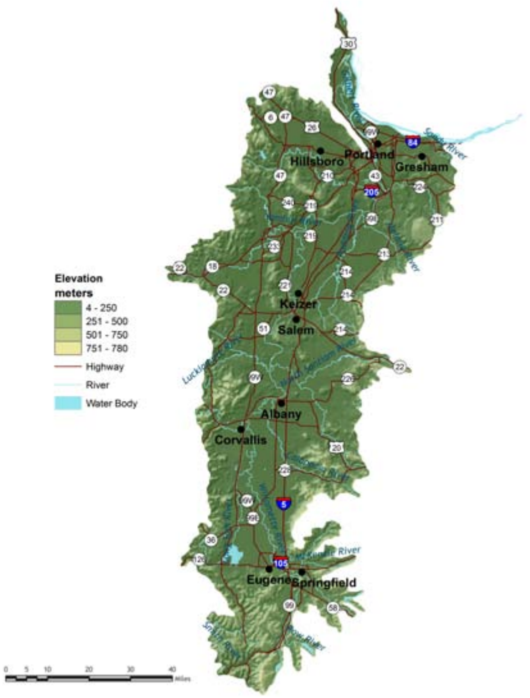


Figure 2. Willamette Valley ecoregion.

Image from *The Oregon Conservation Strategy*. 2006. Salem, OR: Oregon Department of Fish and Wildlife. Reproduced by permission.

Survey shows variable success with riparian tree planting

Slightly fewer than half of 105 riparian tree-planting projects in western Oregon achieved tree survival rates of 75% or more, according to a 2002 study by the Oregon Watershed Enhancement Board.

In 40% of the projects in the study, fewer than half the trees survived.

Projects installed under the Conservation Reserve Enhancement Program were more successful than projects funded by grants. The study's authors attributed this difference to the greater use of site preparation, postplanting maintenance, and tree protection under the program.

Source: Anderson, M., and G. Graziano. 2002. *Statewide Survey of OWEB Riparian and Stream Enhancement Projects.* Salem, OR: Oregon Watershed Enhancement Board.

STEP 1. PLAN YOUR PROJECT

Know your watershed

Your project goals should reflect conditions and needs in your local watershed. Identify what is missing or most in need of enhancement, and set priorities accordingly. In western Oregon, for example, warm stream temperature is commonly identified as the primary water-quality issue, so providing shade to maintain cool water conditions is often a priority.

Begin planning by reviewing watershed assessments from your local watershed council or larger public or private landowners in your watershed (find your local watershed council at *http://www.oregon.gov/OWEB/WSHEDS/wsheds_councils_list.shtml*). Many watershed councils have already identified key constraints and opportunities in watersheds or subbasins (e.g., elevated stream temperatures or lack of large wood).

Know your site

Once you understand watershed conditions and needs, examine your site. Identify specific challenges (e.g., frequent flooding [figure 3], poorly drained soils, abundance and type of weeds, or likely animal damage) that might be serious constraints to a successful planting.

Next, determine what could be enhanced at your site to contribute to overall watershed health. Consider things you might try to change (e.g., amount of shade, bank stability, or livestock use near the stream). Some changes might be easy; others might be difficult or expensive. Some actions will have almost immediate benefits; improvements from other actions won't be evident for years or decades. Make sure any difficult and expensive actions line up with your priorities.

Be sure to consult others. Identify partners in conservation organizations or other agencies who might be able to help identify needs and opportunities at your site (figure 4).

Checklist for Step 1: Plan your project

Time and thought at this stage will lead to a better, more cost-effective project in the long run.

- ☐ Assess needs for the riparian area in the context of watershed conditions and priorities. What is missing or most in need of enhancement?
- ☐ Observe site conditions to determine what actions will address identified needs and have the greatest potential for success.
- ☐ Set goals based on what will help restore key functions in the future rather than what is thought to have prevailed in the past.
- ☐ Consider promoting natural regeneration of trees and shrubs and other passive restoration approaches as well as planting. Try to get the greatest value for your investment.
- ☐ Think about possible obstacles, such as a mismatch between project size and budget, equipment availability, and your time, skills, and commitment. Is there a good chance of success?
- ☐ Develop a site-specific design that addresses local watershed issues, is appropriate for site conditions, and can be accomplished with available resources.

Figure 3. Flooding of a young riparian planting on the North Yamhill River, Yamhill County, Oregon.

Photo by Amie Loop-Frison, Yamhill Soil and Water Conservation District.

Figure 4. Assess current site conditions to determine benefits already being provided, what is needed, and establishment challenges.

Photo by Tara Davis, Calapooia Watershed Council.

Restore functions, not just vegetation

Conditions before European settlement are sometimes used as a guide for desirable riparian conditions. But restoration to presettlement conditions is often difficult or inappropriate. Few accurate or detailed records of those conditions exist, and existing records are snapshots of single moments in time, with no assurance that they are representative of a longer time frame. Also, because riparian ecosystems are complex and change over time, there is no "natural" condition for a given area.

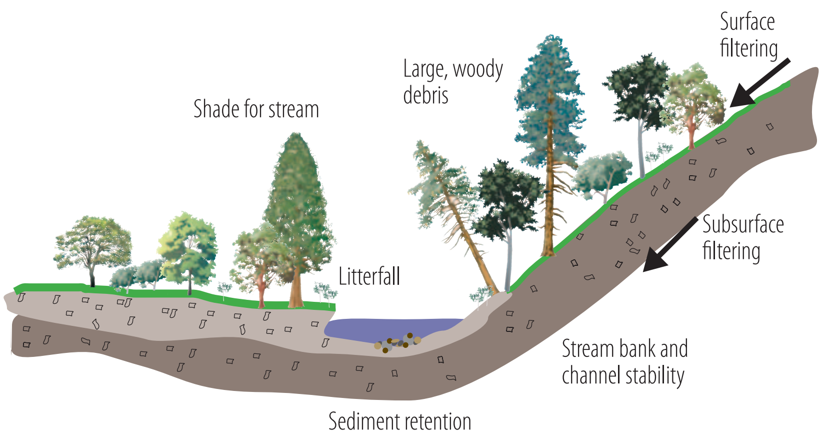


Figure 5. Important functions of a riparian area include shade for the stream, stream bank stability, woody debris for the stream, sediment retention, litter for aquatic organisms in the stream, water filtering, aquatic habitat, and riparian wildlife habitat.

Ecologists recommend restoring or enhancing important riparian functions (figure 5), not just vegetation conditions. For example, development across the Willamette Valley has led to loss and degradation of many habitats, including once-extensive networks of riparian forests, prairies, and savannas. This, in turn, reduced plant and animal populations. One functional goal is to improve habitat by restoring or enhancing conditions that are critical to survival of a species or group of species. See Appendix A (page 22) for more examples of riparian functions.

Riparian vegetation provides many important functions for aquatic habitats. For example, restoration projects designed to aid salmon populations often focus on establishing tree species that create shade, reduce stream temperatures, and drop leaves and insects into the stream. Plantings will eventually provide large wood, which is important for modifying stream channels and creating in-stream habitats.

Riparian areas are also important terrestrial habitats. A well-developed shrub layer provides foraging and nesting sites for migratory songbirds. Large trees are needed to provide nesting or foraging sites for large birds, such as herons and pileated woodpeckers. Large trees take time to develop, but you may accelerate their growth by planting fast-growing species, spacing them far apart, and controlling weeds and other competition. You can also provide some functions normally provided by large trees through interim actions, such as installing nesting boxes (for wood ducks and screech owls) or platforms (for osprey).

Consider passive restoration

Consider whether your site will be able to grow and develop as you desire *without* actively planting it (a passive restoration approach). For example, you may be able to meet tree establishment goals by encouraging natural regeneration of species already present and reproducing on the site (see Appendix B, page 23). Perhaps the only action needed is to remove grazing livestock, weed competition, or intensive cultivation.

Identify obstacles

It is important to assess operational constraints, identify problems, and resolve conflicts during the planning phase. Think about and discuss the following questions with advisors and organizational partners:

- How much money, time, and energy are available for this project?
- Is the budget adequate for the size of the project?
- Do you have a good understanding of demands on resources to accomplish key activities throughout the project (from planning, to planting, to weed control and maintenance)? Can you realistically meet those demands in a timely way, considering your other commitments, health, and access to and skill in using equipment and tools? If not, is there money in the budget to hire help?
- What conflicts might arise with adjacent land uses (e.g., farming or grazing), and how can these be resolved?
- Is there good access to the planting site, and can you move in any needed equipment or supplies?
- Does the site location allow frequent visits for monitoring and maintenance, or will you visit the site only occasionally?
- How will you determine project success? What are the consequences of an unsuccessful planting?

The scale of the project is also an important consideration. Small projects (e.g., dozens to a few hundred trees) allow use of a wider range of techniques, such as hand-cutting competing vegetation, that might be prohibitively expensive on larger projects. As the project's size and complexity increase, so does the need for cost-effective methods of site preparation, planting, and vegetation control. Balance the scale of your project with the budget, time, and other resources available.

Design your project

Although it is helpful to look at other plans and projects, be sure to design a riparian planting that is specific to your site, reflects identified goals, and can be accomplished with available resources.

Your design will need to address many features:

- Width and position of the planting
- Species to plant and type of planting materials
- Plant spacing and arrangement
- Access for people and equipment (for maintenance and monitoring)
- Fencing or other protection from livestock and wildlife

You also need to decide how to prepare the site for planting, how to protect seedlings from weed competition, and how to maintain the planting. The following sections provide more information on these topics. Also see Appendix C (page 24) for additional project design considerations.

Checklist for Step 2: Select and obtain plant materials

Species, source, and stock type are important considerations.

- ☐ Identify species that will provide the key riparian functions you identified during planning.
- ☐ Choose species that are well adapted to your site. Consider tolerance to shade, flooded or waterlogged soils, and drought.
- ☐ Select locally adapted, genetically diverse seedlings or other plant materials that fit your site conditions, management constraints, and budget.
- ☐ Plan ahead. Order seedlings and other types of planting stock well in advance.

STEP 2. SELECT AND OBTAIN PLANT MATERIALS

Species selection

Your plant selections will affect the appearance and function of your riparian planting for decades. Trees and shrubs must be able to survive and prosper when planted and also provide the functions you need in the future. Tables 1 and 2 list characteristics of native trees and shrubs.

Site adaptation

Choose species that are well adapted to site conditions. Moisture—either the lack or excess of—is often the most important factor in both planting success and long-term survival. Consider how the local climate and soils affect moisture, and select species on the basis of moisture needs and flood and drought tolerance. Start by identifying native species growing on similar sites nearby.

Conifers, such as Douglas-fir or western redcedar, are often a priority for riparian plantings in mountainous areas because they provide dense shade and durable, large wood. However, many conifers are not as well adapted to riparian areas in the Willamette Valley that are flood prone or poorly drained and should be selected with caution.

Tolerance to floods and poor drainage

Areas along the stream channel and banks as well as sloughs and swales may be subject to frequent or prolonged flooding. Species selected for these areas must have high flood tolerance. Black cottonwood, bigleaf maple, western redcedar, red alder, white alder, and Oregon ash tolerate flooding (figure 6).

Table 1. Characteristics of riparian and bottomland tree species for the Willamette Valley.

Species	Tolerance to Flooding	Tolerance to Drought	Tolerance to Shade	Comments
Bigleaf maple *Acer macrophyllum*	Medium	Medium	High	Medium-lived tree. Provides early season food for seedeaters and good structural habitat.
Black cottonwood *Populus trichocarpa*	High	Low	Low	Large, fast-growing tree. Prefers moist, well-drained soils. Well-suited for shade and bank stabilization. Popular nesting platform for some birds. Roots well from cuttings.
Douglas-fir *Pseudotsuga menziesii*	Low	Medium	Medium	Tall, long-lived tree. Provides dense shade, durable dead wood, and structural elements. Does not tolerate flooding.
Grand fir *Abies grandis*	Medium	Medium	High	Fast-growing tree. Source of woody debris.
Oregon ash *Fraxinus latifolia*	High	Medium	Medium to High	Slow-growing, medium-height tree. Tolerates poorly drained, heavy clay soils. Older trees provide cavities.
Oregon white oak *Quercus garryana*	High to Medium	High	Low	Slow-growing, medium-height tree. Tolerates poorly drained, heavy soils. Wood ducks and other wildlife eat its acorns.
Ponderosa pine *Pinus ponderosa*	Medium	High	Low	Large, long-lived tree. Moderate growth rate. Provides durable dead wood and structural elements. Native Willamette Valley race is highly tolerant of both poorly drained and droughty soils.
White alder *Alnus rhombifolia*	High	Low to Medium	Low	Fast-growing, medium-height tree. The more common alder in the Willamette Valley and other interior valleys. More tolerant than red alder of poorly drained soils and warm Valley climate. Nitrogen fixer.
Red alder *Alnus rubra*	High	Low	Low	Fast-growing, medium-height tree. Likes moisture, but good drainage. Often struggles on poorly drained sites and in Willamette Valley climate. Nitrogen fixer.
Western redcedar *Thuja plicata*	High	Low	High	Likes moisture, but good drainage. Grows in Willamette Valley riparian areas but may struggle. Premium source of large, woody debris.

A related but often separate problem is soil drainage. Soils on higher terraces in the Willamette Valley often have heavy, fine-textured (clayey) soils with very poor drainage and poor aeration during the rainy season, regardless of whether they flood regularly (table 3). These are essentially wetland soils. Plants on these soils are subjected to saturated conditions for much longer periods than during surface flooding.

Poorly drained soils may be more limiting than floods for plant selection, and planting the wrong species on saturated sites is a common cause of planting failure around the valley. Plants associated with moist conditions in the mountains, such as western redcedar and red alder, may seem appropriate but often grow poorly on heavy (clayey) soils and in hot summer conditions. Trees that do best under these conditions include Oregon ash, Oregon white oak, white alder, black cottonwood, and the native Willamette Valley race of ponderosa pine. Shrubs that do well include Douglas spirea, snowberry, red-osier dogwood, and willow.

Areas along natural river levies and higher edges of floodplains will also flood, although less frequently and for shorter durations. These sites may have well-drained soils and are suitable for a larger group of plants with medium flood tolerance.

Figure 6. Black cottonwood is well suited for giving shade and stabilizing stream banks.

Photo by Brad Withrow-Robinson, © Oregon State University.

Table 2. Characteristics of riparian and bottomland shrub and small tree species for the Willamette Valley.				
	Tolerance to			
Species	Flooding	Drought	Shade	Comments
Cascara buckthorn *Rhamnus purshiana*	Medium	Medium	Medium	Small tree with cherry-like berries favored by many birds.
Douglas hawthorn *Crataegus douglasii*	High	Medium	Medium to High	Small tree. Produces berries in late summer.
Douglas spirea *Spiraea douglasii*	High	Medium	Low	Low, dense shrub. Provides good cover. Spreading. Roots well from cuttings.
Elderberry, blue *Sambucus caerulea*	Medium	Medium	Medium to High	Large, vigorous shrub. Berries ripen in late summer.
Elderberry, red *Sambucus racemosa*	High	Medium	High	Medium shrub. Produces berries in early summer.
Mock orange *Philadelphus lewisii*	Medium	Medium	Medium	Tall understory shrub.
Oregon crabapple *Malus fusca*	High	Medium	Medium	Large, thicket-forming shrub or small tree.
Osoberry *Oemleria cerasiformis*	Low to Medium	Medium	High	Medium shrub. Blooms very early. Fruits ripen in late spring.
Pacific ninebark *Physocarpus capitatus*	Medium to High	Low	Medium to High	Tall understory shrub. Roots from cuttings.
Red-osier dogwood *Cornus stolonifera*	High	Low	Medium	Tall understory shrub. Roots from cuttings.
Salmonberry *Rubus spectabilis*	High	Medium	High	Common mountain riparian species sometimes seen in Willamette Valley. Produces berries in late summer.
Serviceberry *Amelanchier alnifolia*	Medium	Medium	Medium	Large, thicket-forming shrub.
Snowberry *Symphoricarpos albus*	Medium	Medium	High	Low shrub. Roots from cuttings.
Thimbleberry *Rubus parviflorus*	Low	Low	High	Common mountain riparian species sometimes seen in Willamette Valley. Produces berries in late summer.
Vine maple *Acer circinatum*	Low	Low	High	Common mountain riparian species sometimes seen in Willamette Valley.
Willow *Salix* spp.	High	Low	Low	Some willows are tree size; others are large shrubs. Root very well from cuttings. Well suited to bank stabilization and bioengineering projects.

Table 3. Common wetland soils of the Willamette Valley.

Wetland (hydric) soils form when saturation, flooding, or ponding occur for long enough during the growing season that anaerobic conditions develop in the upper part of the soil. Anaerobic conditions are challenging for many species and often a limiting factor for tree and shrub growth.

This table shows Willamette Valley soils listed as hydric. There are other somewhat poorly drained to poorly drained soils (e.g., Amity silt loam) that, while not hydric, can limit species selection and growth of trees and shrubs.

Name	Landform
Awbrig silty clay loam	Terraces
Bashaw clay	Floodplains and terraces
Brenner silt loam	Floodplains and swales
Concord silt loam	Terraces
Conser silty clay loam	Terraces
Courtney gravely silty clay loam	Stream terraces
Cove silty clay loam	Floodplains
Dayton silt loam	Terraces
Grande Ronde silty clay loam	Terraces
Huberly silty loam	Swales and terraces
Panther silty clay loam	Low hills, slumps
Verboort silty clay loam	Floodplains
Wapato silty clay loam	Floodplains
Waldo silty clay loam	Floodplains
Whiteson silt loam	Floodplains

Source: USDA Natural Resources Conservation Service; survey area version date: 12-23-2006. (*http://www.or.nrcs.usda.gov/technical/soil/hydintro.html*)

Drought tolerance

The Willamette Valley has hot, dry summer weather, and moisture stress is often a limiting factor in seedling survival. Sites close to major rivers can actually be quite dry for new seedlings. These riverbanks and levies often have sandy or gravely soils with low nutrient-and moisture-holding capacity, and they dry out rapidly each summer once the rains stop.

Although mature black cottonwood trees thrive along the sandy banks of the Willamette River, this species has relatively low drought tolerance and may be difficult to establish on such sites until its roots reach moisture deep in the soil. In some situations, you can offset this issue with weed control and irrigation.

Shade tolerance

Fast-growing riparian tree species, such as willow, cottonwood, and alder, quickly colonize disturbed areas after floods. But these trees are intolerant of shade and not suitable for planting in the understory of existing trees. Oregon ash, bigleaf maple, grand fir, western redcedar, and many shrub species are tolerant of shade and more suitable for such areas (tables 1 and 2).

Shade tolerance also comes into play as young trees grow and begin to compete with each other for light and other resources. Slower-growing and smaller tree species will tend to fall behind in growth; if these species are not shade tolerant, they will likely die and disappear from the stand. Such competition is part of a natural process but can lead to less diversity and a simpler stand structure than planned for or desired. Address this issue with thoughtful species selection, appropriate spacing and planting arrangements (see Appendix C, page 24), and selective thinning.

Local plant materials

Many species you select for your planting likely grow in many locations in Oregon and North America. For instance, white alder is plentiful in southwest Oregon, and ponderosa pine is abundant in central Oregon. However, plants of the same species from different environments can perform very differently on your site. It is important to find seedlings and planting stock grown from Willamette Valley sources. Buying from a local nursery is not necessarily enough; it is where the seed (or other parent material) comes from that counts, not the place where seedlings are raised.

See “Seed sources and genetic issues” (page 10) for more information.

Table 4. Characteristics of seedling and stock types for riparian plantings.

Stock type	Size (stem caliper and height)	Unit cost range	Comments
Bare root	0.1–0.5 caliper 8–24 inches	$0.15–$0.65	Wide availability. Winter planting. Roots vulnerable to drying. Requires extra care in handling.
Container plugs	0.05–0.3 caliper 6–20 inches	$0.25–$0.80	Fall to spring planting. Requires less skill in handling. Easier for rocky sites.
Container: 1- to 5-gallon pots or 3- to 4-inch by 18- to 24-inch PVC pipe	0.2–2.0 caliper 12–60 inches	$1.00–$10.00	Fall to spring planting. Requires less skill in handling. Survives on droughty sites. Expensive to plant.
Cutting: cane or whip	0.25–1.0 caliper 12–72 inches	$0.20–$0.30 per foot or labor and transport	Presoaking advised. Can cut from local sites. Tolerates flooding. Does not tolerate early weed competition. Grows rapidly.
Cutting: pole	1.0–4.0 caliper 48–96 inches		
Ball and burlap (B&B)	1.5–5.0 caliper 36–240 inches	$25.00–$250.00	Expensive. Instant landscape.

Figure 7. Examples of different stock types. From left: Douglas-fir container plug, 2-0, 1-1, and ponderosa pine plug-1.

Photos from Rose, R., and D.L. Haase. 2006. *Guide to Reforestation in Oregon*. Corvallis, OR: Oregon State University College of Forestry. Reproduced by permission.

Planting stock

Several types of seedlings and stock types are used in riparian plantings (table 4). Consider these characteristics when selecting a stock type:

- Availability
- Handling sensitivity
- Cost
- Ease of transport and planting
- Survival and growth potential

In general, bigger is better. Bigger stock is less likely to be overtopped by competing vegetation and recovers better when browsed. However, it is also more expensive to buy and plant. Ensure that bigger stock has an adequate root system to support the large shoot system.

Bare-root seedlings (figure 7) are grown in nursery beds, usually for 2 years, and then dug and planted during the winter dormant season. They perform well if they receive proper care and are the foundation of many riparian restoration projects.

Common designations for bare-root seedlings:

- 2-0—2-year-old tree grown only in a nursery bed
- 1-1—2-year-old tree grown 1 year in a nursery bed and 1 year in a lower-density transplant bed
- Plug-1—bare-root seedling that started out as a small container seedling and was transplanted to an outdoor nursery bed and grown for 1 year

The 1-1s tend to be larger than 2-0s and have denser, more fibrous root systems. They also cost more. Plug-1 seedlings have characteristics of container and bare-root seedlings and well-developed, fibrous root systems. They are more expensive than other bare-root seedlings.

Advantages of bare-root seedlings:

- Low cost
- Easy to transport
- Wide availability of many forest tree (and some shrub) species

Disadvantages of bare-root seedlings:

- Narrow planting window (winter dormant season)
- Requires skill during planting
- Greater sensitivity to improper handling and planting (e.g., root drying and other damage)

See *Selecting and Buying Quality Seedlings*, OSU Extension publication EC 1196 (*http://extension.oregonstate.edu/catalog*), for more information about stock types.

Container stock (figure 8) is grown in containers and planted with soil intact around the roots. Small container seedlings commonly are referred to as plugs. Sizes range from "Styro-10s" (10 cubic inches of soil in the plug) to 1-gallon pots to large plugs grown in 24-inch-long PVC pipe.

Advantages of container stock:

- Longer planting window (fall through early spring)
- Less skill needed during planting
- Less potential for damage during handling and planting
- Easier than bare-root seedlings to plant on rocky or otherwise difficult sites (plugs)
- Better survival on droughty sites (plugs)

Disadvantages of container stock:

- More difficult to transport to and around the site as size increases
- Potential for introducing weeds
- High cost

Cuttings (figure 9) are dormant sections of hardwood trees and shrubs. They have no leaves or roots. Large cuttings are called whips, canes, or poles. Cuttings are used in the field and in nursery production of container stock. When conditions are right, cuttings root after planting; willow and cottonwood root better than other species. Cuttings are available in sizes from 1 to 10 feet long. For best results, generally select young (i.e., current-year and 1-year-old) wood and soak cuttings before planting.

Figure 8. Large container stock at Stone Nursery, Central Point, Oregon.

Photo by Max Bennett, © Oregon State University.

Figure 9. Cottonwood and willow cuttings, ready for planting. Note that the two cuttings in the foreground have begun to root.

Photo by Chris Van Schaack.

Advantages of cuttings:

- Relatively low cost
- Easy to plant
- Flood tolerance

Disadvantages of cuttings:

- Greater vulnerability to dry conditions
- High sensitivity to weed competition during establishment
- Potential narrowing of genetic diversity (each rooted cutting is a clone)

Ball-and-burlap (B&B) stock has a large ball of soil around the root system held in place with a burlap wrap. These tend to be much larger, much more expensive trees that are generally inappropriate for most restoration situations but may be used in park settings and other green spaces in or near urban areas.

Advantages of ball-and-burlap stock:

- Provide an "instant tree"
- Good survival and growth

Disadvantages of ball-and-burlap stock:

- High cost
- More difficult to plant than other stock types

Many commercial forest nurseries in the Pacific Northwest grow plants suitable for riparian restoration projects. The popularity of these projects, and the demand for planting stock, has grown enormously in the past decade. Most nurseries grow some stock on speculation (i.e., based on expected demand), which they sell on a first-come, first-served basis. These supplies don't always meet demand, so order early for the best availability of species, seed source, and stock type.

You can also contract with nurseries to grow plants to your specifications. This gives you the greatest control of seed source. A minimum number of seedlings (e.g., 2,000) is required for such contracts, and you will likely need to start this process 2 years before your anticipated planting date.

Many local soil and water conservation districts and some chapters of the Oregon Small Woodlands Association have annual plant sales, which are a good place to purchase smaller numbers of plants. Be sure to ask about seed source.

Use the following resources to find nurseries that sell or specialize in native plants:

- *Sources of Native Forest Nursery Seedlings* (publication from the Oregon Department of Forestry): *http://www.oregon.gov/ODF/privateforests/docs/ForestNurserySeedlingSources.pdf*
- Oregon Association of Nurseries: *http://www.nurseryguide.com/*
- Oregon State University Extension forester
- Oregon Department of Forestry stewardship forester

Seed sources and genetic issues

To ensure that plants are adapted to your site, select planting stock grown from a local seed source. How local is "local"?

Because climate varies so much over short distances in northwest Oregon, there is no rule of thumb (e.g., 50 miles) for how far trees and shrubs can be moved safely from their source. Instead, seed zones have been established to minimize risk.

Seed zones are geographic areas with fairly uniform temperature, rainfall, and other climatic factors. If the area includes major elevation changes, elevation bands within each zone further define areas with important similarities in conditions.

Trees can be planted safely within their zone of origin based on both the geographic seed zone and the elevation band. Planting in a higher or lower elevation band from the zone of origin increases the risk that the plant will adapt poorly to its new environment.

Specify the seed zone and elevation (to the nearest 500 or 1,000 feet) when ordering seedlings.

Seed zones have been established for most conifer species, red alder, and black cottonwood. Relatively little is known about genetic variability among other native riparian hardwoods and shrubs. In the absence of specific zones for a species, use basic westside zones to guide seed transfer in other hardwood and shrub species (figure 10). Seed transfer should be relatively safe within these zones. In practice, planting stock is not always available from your desired seed zone and elevation.

- Moving between two adjacent seed zones, especially close to their boundaries, may pose little risk, as long as there is relatively little difference in temperature and precipitation.
- Avoid moving seed across major environmental divides, such as from the interior valleys to the coast and vice versa.
- Moving up in elevation (more than 1,000 feet) increases the risk of frost damage. Moving down in elevation poses less risk, although growth may be slower.
- Regardless of zone boundaries, plants will be vulnerable to drought stress if seed is moved from areas of high precipitation (i.e., above 60 inches) to areas of low precipitation (i.e., below 30 inches).

For more information, see *Selecting Native Plant Materials for Restoration Projects*, OSU Extension publication EM 8885 (*http://extension.oregonstate.edu/catalog*).

Figure 10. Basic seed zone map for western Oregon. Use for hardwoods and other species that do not have their own designated seed zones.

Image by Glenn Howe, © Oregon State University.

STEP 3. PREPARE THE SITE

Streamside restoration sometimes begins with a clean slate—an agricultural field free of established weeds, ready to plant. More often, the site has well-established, invasive perennial weeds, such as Himalayan blackberry, Scotch broom, and reed canarygrass (figure 11), that must be controlled to allow good establishment of native trees and shrubs. This control is generally best done before planting, as part of site preparation.

Good site preparation does not guarantee long-term survival and growth, but it helps. Seedlings get off to a better start, and future maintenance is easier. It is usually much easier and less expensive to control tough weeds before planting than after. You may need to spend two seasons getting your site ready for planting.

Some aggressive site preparation techniques are quite disruptive, can cause unintended damage, and should be used with caution after careful consideration of the situation. Select practices appropriate to the problems and risks at the site, keeping in mind that a minimalist approach to riparian planting often leads to failure.

Checklist for Step 3: Prepare the site

Weed competition is a serious obstacle to successful establishment of riparian plantings; it is usually easier to control competing vegetation before planting than after.

- ☐ Anticipate future weed problems. Review your site assessment (Step 1, page 2) to identify weeds, barriers to effective planting, access issues, and management limitations.
- ☐ Allow enough time. It may take two or more seasons to get control of some aggressive weed species.
- ☐ Choose site preparation methods that kill the root systems of perennial weeds, such as blackberry and Scotch broom. Live roots will resprout.
- ☐ Consider effectiveness, duration, and cost. Herbicides are often the most effective and least costly method for controlling competing vegetation. Tilling, cutting, mowing, pulling, grubbing, and mulching can also be effective.
- ☐ Plan ahead to minimize potential new problems. Aggressive site preparation may remove competing weeds but also will expose bare soil, which can lead to new (possibly worse) weeds and the risk of erosion.

Seedling survival and growth

Weeds compete with seedlings for moisture and other critical resources. Research has demonstrated that eliminating weeds from a relatively small area around the seedling can dramatically improve seedling survival. Substantial improvements in seedling growth, however, occur only when weeds are nearly completely eliminated. It is easier and cheaper to achieve high seedling survival than rapid seedling growth.

An effective approach to ensure good survival is to create a weed-free area (3 feet by 3 feet or 4 feet by 4 feet) for each seedling before planting and maintain that area for at least 2 years after planting (figure 12). Woodland owners regularly achieve 80% to 90% survival of bare-root seedlings planted in unirrigated, upland soils with this approach.

The weed-free area can be spots, strips, or a broadcast treatment (the entire field) depending on your objectives. Choose the target area and control methods on the basis of site conditions and your preferences, skills, and equipment.

Figure 11. Tall-growing reed canarygrass competes aggressively with transplanted seedlings.

Photo by Brad Withrow-Robinson, © Oregon State University.

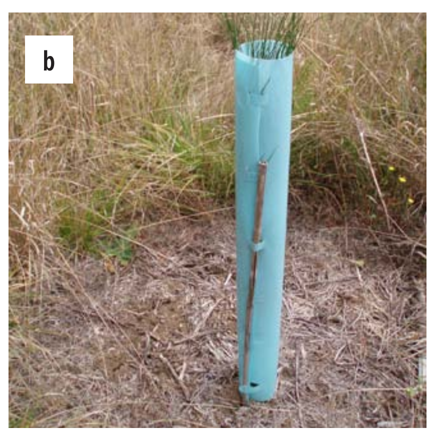


Figure 12. Creating a weed-free strip (a) or patch (b) lessens moisture competition for newly planted tree seedlings. Tree shelters protect seedlings from spray and browsing animals.

Photo 12a by Brad Withrow-Robinson, © Oregon State University. Photo 12b by Donna Schmitz, Benton Soil and Water Conservation District.

Competing vegetation

Table 5 describes site preparation methods for the two types of competing vegetation: herbaceous and woody. The most effective methods kill shoots and roots of target weeds. Removing only the aboveground portion of competing vegetation provides good access and temporarily reduces competition. However, if root systems are not killed or removed, perennial weeds will resprout and compete vigorously with planted seedlings. Future control will be more difficult. There is a clear trade-off between less effective site preparation and an increased need for future maintenance.

Weed control is a means to an end. Your goal is not to kill weeds, but to allow seedlings to survive.

Herbaceous grasses and broadleaf weeds compete vigorously with newly planted trees and shrubs. Their effect is strongest very close to the seedling and in the first few years after planting. Grasses are particularly competitive for several reasons:

- Grasses have a dense, fibrous root system that rapidly absorbs soil moisture.
- Grasses start growing earlier in the season than most woody vegetation and use available soil moisture by early summer. Seedlings need this moisture to survive summer drought.
- Some grasses spread rapidly via underground runners (rhizomes) and can resprout from root fragments.
- Dense herbaceous cover is good habitat for voles (meadow mice), which often kill seedlings by stripping their bark.

Woody vegetation, such as Himalayan blackberry and Scotch broom, competes with seedlings for soil moisture and sunlight. These plants can remain highly competitive much longer than herbaceous plants. Suppressing these aggressive, nonnative, weedy shrubs long enough for trees to establish can be a challenge. A combination of control methods is often required (figure 13).

See *Managing Himalayan Blackberry in Western Oregon Riparian Areas*, OSU Extension publication EM 8894 (*http://extension.oregonstate.edu/catalog*), for more information about controlling blackberry in riparian areas.

Mechanical control

Mowing is commonly used to clear herbaceous plant debris and woody species, such as blackberry, before planting. However, mowing alone is not an effective way to control perennial weeds, which simply regrow after cutting. In some cases, multiple annual mowings over several years can substantially reduce blackberry cover and vigor. Tractor-mounted mowers are preferred where access and slopes permit, although soil compaction might be a concern. Soil compaction has been shown to reduce seedling growth in upland forests. Where machinery use is not feasible, use machetes, loppers, or brush cutters. A chainsaw with a hedge-trimmer attachment is also effective.

Figure 13. Example of Himalayan blackberry control in a riparian terrace next to a farm field: (a) just prior to mowing with a rotary mower, (b) in the middle of the first growing season, and (c) after 4 years of growth. Site preparation included two mowings followed by a fall application of glyphosate. Postplanting treatments included spot spraying with glyphosate and hand weeding.

Table 5. Site preparation methods.

Method	Effectiveness and duration[1]	Cost/acre per application[2]	Comments
Grasses and herbaceous vegetation			
Herbicides: applied with vehicle and boom spray or hose, or with backpack or hand sprayer	High 1–2 years	$60–$200	Can apply to strips or planting spots. Minimum area is 3 feet by 3 feet, centered on seedling. Dead plant material temporarily protects soil and delays weed reinvasion from seed.
Mechanical: tilling	High 2–4 months	$100–$200	Weeds sprouting from seed rapidly reinvade exposed soil.
Mechanical: mowing	Low 1–4 weeks	$50–$150	Mowing does not stop moisture competition but may reduce rodent problems. Must be repeated often.
Manual: scalping, hoeing	Medium 3–6 weeks	$120–$360	Minimum area is 3 feet by 3 feet, centered on seedling. Weeds sprouting from seed rapidly reinvade exposed soil.
Mulch (mats or other)	Medium 1–2 years	$150–$400 for mats	Mats must be well secured and flat on ground. Minimum area is 3 feet by 3 feet, centered on seedling. Mulch mats can harbor rodents and might wash away in high water.
Woody shrubs			
Herbicides: applied with vehicle and boom spray or hose, or with backpack or hand sprayer	High 1–3 years	$60–$250	Complete spray coverage is most effective. Dead plant material temporarily protects soil and delays weed reinvasion from seed.
Herbicides: cut-stem or basal-bark treatment	High 1–3 years	$50–$120	Apply water-soluble formulations to cut stem surfaces. Apply oil-soluble formulations to penetrate bark. Standing dead material provides dead shade. Debris and leaf litter cover soil.
Mechanical: grubbing roots, raking	High 1–2 years	$600–$1,000	Weeds sprouting from seed rapidly reinvade exposed soil.
Mechanical: mowing	Low 1–4 weeks	$100–$300	Doesn't kill roots, which rapidly resprout. Must be repeated often.
Manual: slashing	Low 1–6 weeks	$400–$600	Doesn't kill roots, which rapidly resprout. Must be repeated often.
Manual: grubbing roots	High 1–2 years	$1,000–$3,000	Weeds sprouting from seed rapidly reinvade exposed soil.

[1] Effectiveness at reducing competition for site resources; duration is the period that competition is significantly reduced.

[2] Site preparation costs for each practice are highly variable and depend on site-specific situations. Costs listed here reflect a typical range of site conditions, but actual costs might be higher. Lower costs are associated with larger areas, easier ground, and forestry or agricultural contractor rates. Higher costs are associated with smaller projects, difficult conditions, and landscape contractor rates.

Hand scalping (i.e., scraping the vegetation down to bare mineral soil with a shovel or planting hoe) is a simple method for removing grasses and herbaceous weeds at planting (figure 14). For this method to be effective, you need to clear a 3- to 4-foot-wide area and remove many of the roots. This is labor intensive and provides only temporary relief from competition. Hand scalping usually needs to be repeated at least once during the first growing season and also the following year. Using mulch mats or other mulch materials after hand scalping can help prevent weed reemergence (Step 5, page 18).

Mechanical scalping with a brush-blade-equipped tractor or other specialized equipment can be an effective means of removing brush if roots are also removed. This intensive and disruptive method is not suitable for many restoration situations because it can lead to soil compaction, erosion, and weed invasion.

Manual pulling is extremely labor intensive but can be effective if done thoroughly (i.e., remove all roots and rhizomes of blackberry). Like tillage and mechanical scalping, pulling can also leave lots of disturbed soil, increasing the risk of erosion and weed invasion.

Grazing is not an effective means of site preparation but may be suitable in some cases once seedlings are well established.

Tillage (including plowing, harrowing, and rototilling) can clear ground and break up sod, allowing easy planting and a clean start. But unless it's done repeatedly during the season before planting, tillage alone is generally not very effective against perennial weeds because of their ability to resprout from root fragments.

Tillage can also create several unintended consequences. It leaves the ground open and vulnerable to erosion and recolonization by other weeds. A freshly tilled field can be a sticky mess at planting. Rototilling strips (3 to 4 feet wide) can minimize some of these drawbacks.

Subsoiling, or ripping, is a special form of tillage that may be justified in cases of serious soil compaction, such as on pastures used for winter grazing. Combine tillage with mulch mats or other methods to maintain the target weed-free area after planting.

Chemical control

Herbicides are an effective, and versatile, method for controlling perennial weeds before planting. They can be applied with power-driven spray equipment or backpack sprayers to provide control across a range of terrains without soil disturbance. Use herbicides according to your needs; create weed-free patches or strips to ensure good survival, or use a broadcast application to clear the entire site. Timing is critical, and herbicide effectiveness depends on the chemical used and species targeted.

Timing

If applied when weeds are actively growing, herbicides containing glyphosate will kill common perennial grasses (e.g., reed canarygrass, bentgrass, and tall fescue), annual grasses, and other herbaceous vegetation. Application rates will vary depending on the weeds present. Glyphosate is a foliar-active herbicide, so it will not control weeds that emerge from seeds after treatment. Additional methods will be needed to maintain weed control in the first few seasons after planting; these could include mulch, reapplications of glyphosate, or soil-active herbicides.

For blackberry and other woody species, herbicide application is most effective when plants have not been recently cut or mowed before spraying. When this is not practical, mow early in the season, and allow shoots to regrow before spraying.

Formulations

Several formulations of both glyphosate and triclopyr can control blackberry, Scotch broom, and other woody species. Chemical formulation and timing greatly affect effectiveness on target weeds and sensitivity of nontarget plants. These chemicals will damage or kill the hardwood trees and shrubs commonly included in riparian plantings, which is why controlling weeds during site preparation, before planting, is so important. Use extreme care when spraying, especially near riparian areas.

Consult the *Pacific Northwest Weed Management Handbook* (*http://pnwhandbooks.org/weed*), the Oregon Department of Forestry, your local soil and water conservation district, and your local Extension office for more information about formulation and timing of herbicide applications. Also see "Important information about using herbicides" (page 15).

Minimizing erosion

"Light touch" site preparation may reduce the risk of erosion but provide poor control of competing vegetation. More aggressive site preparation may provide excellent weed control but expose bare soil. This is a particular concern on or near stream banks that are washed by storm flows.

Strategies for minimizing erosion:

- Prior to site preparation on stream banks and terraces, plant and establish willow cuttings near the channel to dissipate stream energy.
- Remove competing vegetation only in small patches along a stream rather than in a continuous section.
- Use erosion-control cloth and other bioengineering approaches (figure 15).
- Use herbicides, and retain dead material to protect soil.
- Establish cover crops, or maintain untreated strips of vegetation.

Figure 14. Scalping provides only a temporary "leg up" on weed competition.

Photo by Paul Oester, © Oregon State University.

Figure 15. Erosion-control matting was used on this section of Thompson Creek in Jackson County, Oregon, after a steep, eroding bank was graded back to a more desirable angle, exposing bare soil. The site was revegetated with willow cuttings (visible as stakes in the fabric) and grass.

Photo by Applegate Partnership and Watershed Council.

Important information about using herbicides

- Use a herbicide registered for your intended use.
- Read the herbicide label, and follow the instructions. The label is the law!
- When appropriate, use formulations that are labeled for aquatic use. Consider the toxicity of both the herbicide *and* the surfactant.
- Mix herbicides well away from riparian areas.
- Wear protective clothing and safety devices as the manufacturer's label instructs.
- Avoid spraying on windy or hot days (above 75°F) to minimize herbicide spray drift and risk of volatilization (turning into a vapor). The risk varies with the herbicide.
- For herbaceous vegetation, spot-spraying or wipe-on techniques are often a suitable alternative to broadcast applications.
- For woody vegetation, injection or cut-surface treatments can be appropriate.

The Oregon Department of Agriculture regulates herbicide use. The Oregon Department of Forestry regulates applications on forestland, including forested riparian buffers. Land in other land-use categories may have different regulations. Contact the appropriate agencies for current information about restrictions on herbicide use near streams.

See the *Pacific Northwest Weed Management Handbook* (*http://pnwhandbooks.org/weed*) and other resources listed under "For more information" (page 27), for more details on herbicide application and regulation.

STEP 4. PLANT YOUR TREES RIGHT

Well-established guidelines for tree planting in forestry and horticulture generally are applicable for riparian plantings. See *The Care and Planting of Tree Seedlings on Your Woodland*, OSU Extension publication EC 1504 (*http://extension.oregonstate.edu/catalog*), and other resources listed under “For more information” (page 27).

Checklist for Step 4: Plant your trees right

Proper planting helps shape the future of your project; many problems with seedling survival can be traced back to improper care and handling.

- ☐ Plant at the right time of year—during the winter dormant season for bare-root trees and from fall through early spring for container seedlings.
- ☐ Treat seedlings with care from the time they leave the nursery through transport, short-term storage, on-site storage, and planting. Keep bare-root plants cool and moist, and minimize physical damage.
- ☐ Use proper tools and planting techniques. Select suitable microsites for seedlings, such as the in shade of logs or on well-drained hummocks.
- ☐ Use a planting layout suited to your access needs, maintenance plan, and equipment. Accommodate differing plant growth patterns and competition among species (see Appendix C, page 24).

When to plant

Plant bare-root seedlings during the winter dormant season, preferably when soils are above 40°F. Avoid planting during warm, dry, or windy weather. Plant container seedlings (ranging from small plugs to ball-and-burlap stock) from fall through early spring. If soils are moist and warm (above 40°F), fall planting may be advantageous since seedlings’ roots may experience significant fall root growth. Plant hardwood cuttings in the dormant season from late fall to early winter.

Seedling care and handling

Once dug or “lifted” at the nursery, bare-root seedlings are vulnerable to damage during packing, transport, storage, and planting. Many problems with seedling survival can be traced back to improper care and handling:

- Keep seedlings moist. Roots dry out rapidly when exposed to sun or wind. If roots appear dry, fine roots and root tips are likely damaged or dead already.
- Keep seedlings cool. When seedling temperatures exceed 42°F (and especially when temperatures remain above 50°F for more than a few hours), they begin “growing in the bag,” using energy needed for survival and growth after planting.
- Handle seedlings with care. Physical damage can result from crushing, dropping, and excess vibration. Avoid tearing roots when unpacking seedlings.

Table 6 lists recommendations for seedling care and handling, focusing on bare-root stock.

Planting tools and techniques

Use the tool that is best suited to the seedling’s root system and to soil and site conditions.

For bare-root and container plantings, a heavy-duty, reinforced shovel works well across a range of Willamette Valley soil conditions and is easier for many people to use than a hoedad planting hoe (figure 16). Match the shovel blade size to the seedling’s root system. Other hand tools include the dibble and planting bar (suitable for small plugs). Common garden shovels are often unsatisfactory.

Figure 16. Use suitable tools and good planting techniques, and take care to plant each seedling well. Sturdy shovels (a) and planting hoes (b) can produce good results.

Photos by Brad Withrow-Robinson, © Oregon State University.

Figure 17. Auger planting can be helpful for large stock types.

Photo by Brad Withrow-Robinson, © Oregon State University.

Tractor-mounted or handheld power augers can work if the soil is not too heavy (clayey) or rocky (figure 17). Auger planting is especially useful for large container stock.

Take advantage of microsites (i.e., small differences in site conditions, such as soil, elevation, and shade, that affect seedling survival and growth). The shade of a log or other debris can help a seedling endure summer drought. Avoid or minimize hazards. For example, a depression that ponds each winter is not the right site for any but the most flood-tolerant species. Figure 18 shows common tree-planting problems.

Bare-root stock

- Create a hole large enough to position the roots naturally.
- Prepare soil of adequate quantity and quality to fill back around roots without debris or air pockets.
- Position the tree straight and at the proper depth, using the nursery soil line as a guide. Planting too shallowly is a common problem; the root collar (the point where the highest root joins the tree stem) should not be exposed.
- Refill the hole, packing soil around the roots so the tree is held firmly but roots are not compressed.

Plugs or container stock

- Keep the soil–root mass intact.
- Ensure that stock is well watered before planting.
- Prepare a hole large enough to provide some loose soil around the soil–root mass for unimpeded root growth.

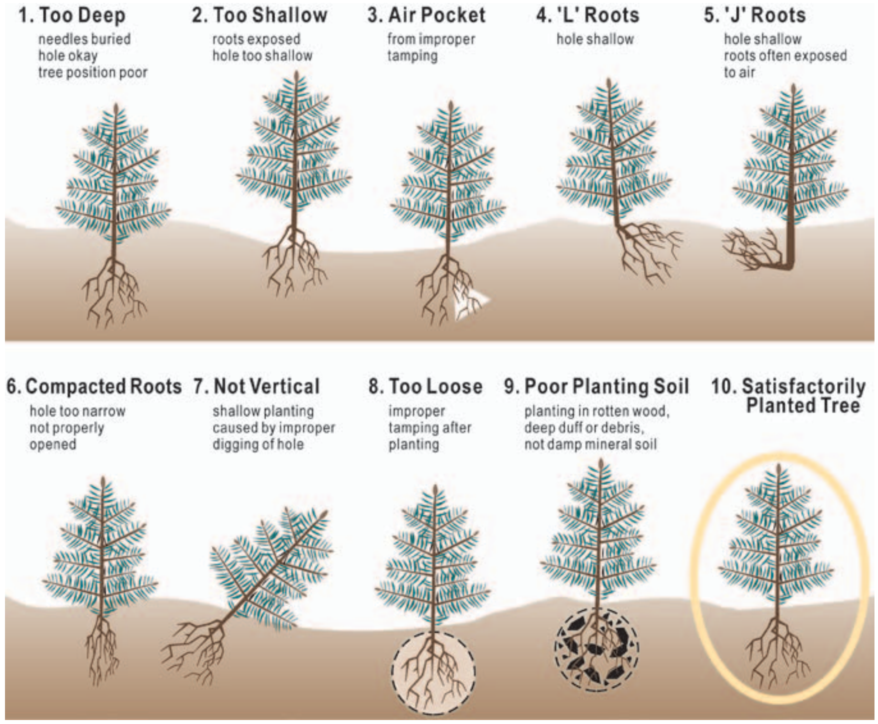


Figure 18. Common tree-planting problems.

Image from Rose, R., and P. Morgan. 1992. *Guide to Reforestation in Western Oregon*. Corvallis, OR: Oregon State University College of Forestry. Reproduced by permission.

Cuttings

- Depending on cutting size and planting depth, you can push cuttings into moist soil or place them in holes excavated with hand tools or machinery.
- Cuttings are less fragile than bare-root seedlings, but general rules for handling, storage, moisture, and temperature apply.
- Soak willow and cottonwood cuttings in water for 1 to 10 days before planting.
- Plant cuttings right side up (i.e., the buds point up).
- Cuttings need to be planted deeply enough so that emerging roots can access moist soils throughout the summer drought period.

Spacing and arrangement

The planting arrangement helps shape stand development and, ultimately, riparian functions. Plant according to the design you developed during your planning process (Step 1, page 2). Use a layout suited to your access needs, maintenance plan, and equipment. If planting a mixture of species, be sure to accommodate differing plant growth patterns and competition among species. See “Spacing and arrangement” in Appendix C (page 24) for more information.

Remember that planting is just one step in creating a riparian woodland. Other actions, such as weed control and thinning, will likely be required to keep the planting on track and achieve your functional goals.

Table 6. Care and handling of bare-root seedlings.

Stage	Recommended practices
Long-term storage (more than 3 days)	• Store in a cooler at 33°F to 36°F. • Use packaging that prevents moisture loss. Most nurseries store and ship seedlings in waxed bags or boxes that "breathe" but prevent water loss.
Transport from nursery	• Use a refrigerated or insulated truck or reflective tarp (white exterior, silver-foil interior) over seedlings in an open-bed truck. • Do not expose seedling containers to direct sunlight. • Avoid using dark-colored tarps, which build up heat. • Travel during cool times of day if possible.
Short-term storage (a few hours to 3 days)	• Store below 42°F (ideal temperature range is 34°F to 36°F).
Transport to planting site	• Use proper packaging for seedlings and a reflective tarp. • Do not transport in the open; keep covered. • Do not stack bags more than two high. • When arriving at the site, store seedlings in shade. • Do not take more seedlings than can be planted in 1 day.
At planting site	• The greatest risk of damage from moisture loss, temperature, and physical handling is at this stage. • Handle seedling boxes or bags gently; do not throw or drop. • Reseal partially empty bags. • Avoid rubbing or tearing roots when taking seedlings out of the storage bag and putting them in the planting bag. Do not cram too many in the bag. • Seedlings may be dipped in water (for 1 minute at most) before placing in a planting bag, but do not store in water or the roots will die. • Do not leave seedlings unprotected on the ground, and make sure roots stay moist.

Checklist for Step 5: Take care of the planting

Maintenance after planting often makes the difference between success and failure.

- ☐ Control competing vegetation for 2 years or more after planting to ensure good survival. Controlling invasive weeds and other competing vegetation leaves more soil moisture and other resources for seedlings.
- ☐ Minimize animal damage problems—from livestock or wildlife—by using seedling protective devices, fencing, or repellents as needed. Try to anticipate problems during your initial site assessment (Step 1, page 2), but monitor and respond to problems if they occur.
- ☐ Irrigation can help improve seedling survival and growth, particularly for water-loving species on droughty soils. Consider the labor and expense involved, and select species that can survive on the site over the long term without irrigation.
- ☐ Visit the site periodically to monitor seedling survival and growth and determine maintenance needs. The first season after planting is the most critical, but maintenance may be needed for several years before seedlings are free to grow.

STEP 5. TAKE CARE OF THE PLANTING

Maintenance weed control

The task at this stage is to maintain the weed control achieved before planting. Without continued control, weeds will quickly return and affect seedling survival and growth. This is a common source of failure in riparian plantings.

Once the planted species begin to shade a significant portion of the ground, weed control becomes much easier. The time required to reach this stage varies. With effective weed control, conifer plantings on unirrigated, upland sites in western Oregon commonly reach this point (called "free to grow") in 4 to 6 years. There is less research or experience for riparian plantings to guide us, so plan for ongoing weed control in your planting for at least that long.

An added challenge in postplanting vegetation control is the need to mow, trim, or spray around vulnerable seedlings. If site preparation was effective, the main concern will be annual grasses and broadleaf weeds. Try to maintain the same control targets established before planting (e.g., a 3-foot by 3-foot or 4-foot by 4-foot patch or a 3- to 4-foot-wide strip).

Mowing is popular in young plantings. With available tools ranging from tractor-mounted mowers to handheld weed trimmers, mowing can keep woody weeds under control across a range of terrains and planting sizes. Mowing alone is not a good way to control herbaceous plants and gives only modest relief from moisture competition.

Mulches are effective for suppressing weeds around planted seedlings and retaining moisture into the summer. Various mulch materials are available.

Weed mats are made of woven synthetics, paper, or other materials (figure 19). They are placed over bare ground and fastened with landscape pins or rocks and soil. Commercial products include Vispore, Pak, and Brush Blanket. Longevity varies from one to several seasons. Mats come in various sizes; the recommended minimum is a 3-foot square. Mats are effective against grass and forbs but not resprouting woody vegetation. Mats have several disadvantages; they are relatively expensive ($0.75 or more per mat) and labor intensive to install, provide shelter for rodents, and can move if the area floods.

Organic materials used for mulching include straw and wood chips. Newspapers, cardboard, and other low-cost alternatives can be used as mats. These materials are inexpensive and readily available (figure 20), but they can be a source of weed seed, are not as effective as weed mats for suppressing weeds, and may decompose too quickly or be swept away by floods.

Figure 19. Mulch mats under ponderosa pine seedlings on a dry site in southwest Oregon.

Photo by Applegate Partnership and Watershed Council.

Figure 20. Organic material such as bark or wood chips is often used as an inexpensive form of mulch and weed protection.

Photo by Applegate Partnership and Watershed Council.

Herbicides can be an effective and efficient way to control weeds after planting, but seedlings are also susceptible to commonly used herbicides (e.g., glyphosate). Avoid damage by directing spray at weeds and shielding seedlings to prevent contact with leaves or green bark. Glyphosate and other foliar-active herbicides have no soil activity; they kill what is already growing but don't prevent establishment of new weeds. Two or more treatments may be needed each season to control emerging weeds. Many formulations of glyphosate are available. Check the label to see if a product allows your intended use.

Animal damage control

Animal damage is another common cause of plant mortality in riparian plantings. Hardwood species are particularly attractive to many animals. Carefully assess the need for protection, taking into account the food and shelter available in the area for various animal species. Physical methods of damage prevention (e.g., fences, cages, and tubes) are useful, but they are also expensive and require periodic inspection and maintenance. Using large planting stock and controlling weeds to promote rapid seedling growth will help minimize many animal damage problems.

Beaver and nutria can cause extensive damage to young seedlings. Removing these animals may be an option; however, the site will likely be repopulated from adjacent areas. Plantings quickly grow beyond nutria but may remain attractive to beaver for many years.

Protection methods include individual tree protectors (e.g., 2- or 4-inch wire mesh cages), chicken wire or sheet metal loosely wrapped around larger tree trunks, and fencing between the planting and stream.

Depending on your situation, you may be able to meet your objectives using a species not preferred by beaver, such as ninebark. Consult with local experts. Small, isolated plantings that are the only woody plants in the neighborhood are more attractive and more vulnerable and will likely require more protection than large plantings adjacent to other areas of woody vegetation.

Deer typically browse young seedlings early in the growing season, when new shoots are tender. Deer will browse up to about 3.5 or 4 feet. If deer are a problem, you need to protect trees' leaders until they grow past this height. If you fence an area, the fence must be at least 8 feet high to keep out deer.

Tree shelters (figure 21) and plastic mesh tubing, supported with a bamboo or wooden stake, are effective but expensive and labor intensive to install ($3 to $6 per tree installed). Big-game repellants (e.g., Deer-Away and BGR) must be applied every 2 weeks in spring and early summer to be effective against lighter browsing. Bud caps, flexible netting, and other materials are less expensive than tree shelters and sometimes prevent browsing.

Mice and voles can be very damaging to young plantings. They can thrive under a tall, dense cover of grassy weeds. When vole populations surge, they will eat the bark on seedlings of all species, girdling and killing trees up to 1 to 2 inches in diameter. Most damage occurs during winter. The most effective control is to eliminate cover by mowing grasses short and eliminating grassy weeds near seedlings. The standard 3-foot by 3-foot or 4-foot by 4-foot area used to reduce weed competition works well for preventing vole damage, too. Tree shelters and aluminum foil (wrapped around the base of seedlings) can also protect seedlings.

Figure 21. Tree shelters protect seedlings from several forms of animal damage but are labor intensive and expensive to install.

Photo by Donna Schmitz, Benton Soil and Water Conservation District.

Livestock (e.g., cows, horses, sheep, goats, and llamas) find young seedlings palatable and can heavily damage unprotected seedlings. The best way to keep livestock out of planted areas is standard woven wire or electric fencing.

Irrigation

Although all plants can benefit to some degree from irrigation, it is usually not essential. Selecting appropriate species and planting stock, using proper handling and planting techniques, and effectively controlling weeds will help ensure success in the absence of supplemental water.

Irrigation can help seedlings survive summer drought and improve seedling vigor and growth. Hardwoods are more susceptible to drought than conifers. Irrigation will be a temporary practice, so you must select species that will survive without irrigation after they are established.

Carefully evaluate the need for irrigation. If your planting is on farmland with water rights and irrigation equipment, irrigation may be feasible and effective. On other sites, irrigation can be time consuming and expensive.

Irrigation is most appropriate under the following conditions:

- During the first one or two growing seasons, to help seedlings establish
- On very coarse soils (e.g., sandy or gravelly) with minimal water-holding capacity
- When planting water-loving species (e.g., alder, willow, and cottonwood)
- When water rights are available

Irrigation methods include sprinklers, drip systems, and hand watering. Select a method on the basis of cost and available equipment, labor, and water. If you don't have a water right to irrigate, you may have to carry water in from off site. Contact the Oregon Water Resources Department (*http://www.wrd.state.or.us/*) for more information.

For maximum benefit, begin watering by early summer, before plants develop high levels of moisture stress. Plan to water every 10 to 14 days, tapering off as summer progresses. Drying down at the end of the growing season helps induce dormancy and increase winter hardiness, so avoid frequent irrigation in late summer.

Tree seedlings may not expand their root area much in the first growing season. They depend on nearby soil for moisture. Monitor this area. Water deeply and slowly to thoroughly wet the rooting zone.

STEP 6. MONITOR AND LEARN FROM RESULTS

Monitoring your riparian planting allows you to complete several essential activities:

- Identify immediate maintenance needs to ensure trees survive and grow.
- Determine whether goals for tree survival and growth are being met (implementation monitoring).
- Determine whether goals for riparian functions are being met (effectiveness monitoring).
- Improve future riparian restoration efforts by learning which treatments or techniques worked, which didn't, and why (adaptive management).
- Document project implementation and results for funding agencies.

Checklist for Step 6: Monitor and learn from results

Monitoring is an essential part of a successful project, but in practice it is often neglected.

- ☐ Build monitoring into your initial project plan.
- ☐ Inspect the planting early in the first growing season to assess problems while there is still time to address them. Plan for one or more follow-up inspections during the first growing season and annual inspections thereafter until trees are free to grow.
- ☐ Document the project. Keep a log of project activities and monitoring observations.
- ☐ Establish photo points to document change in riparian conditions over time. Also consider more intensive monitoring or educational efforts, such as demonstration plots.

Recordkeeping and evaluation

Before implementing the project, develop a monitoring plan that addresses these questions:

- What do you want to monitor (e.g., tree survival, shade, and bank stability)?
- How will you measure or evaluate these items?
- When do key monitoring tasks need to be done?
- What is appropriate given your goals, time, skills, and budget?

Good documentation is essential:

- Prepare an overall project description including location, site conditions, site preparation, and maps and descriptions of planted areas to be monitored.
- Compile planting records, and note what was planted, where, and how.
- Record all project activities by date in a project log.
- Note results from periodic visual inspections and other forms of monitoring.

Consider marking the locations of planted trees with surveying ribbon or wire flags. Although time consuming, this will make it easier to locate trees for needed maintenance and monitoring and help ensure that you don't accidentally damage or cut trees.

Periodic visual inspection

This is the simplest and most important type of monitoring. The main purpose is to see how the planting is doing and to decide what, if any, corrective actions are needed to make sure trees survive and grow adequately to meet project goals. Plan for a visual inspection of the planting site at least once per season:

- Are grasses or other weeds encroaching on or threatening to overtop planted trees?
- Is there evidence of browsing, girdling, or clipping of stems?
- What steps need to be taken to correct the problems?
- Are trees vigorous and healthy?
- Are trees of some species or trees in certain areas doing better than others? If so, why?

Note your observations in the project log. The most critical time for inspection is the spring after planting, while there is still time to address emerging problems.

Photo monitoring

A series of photos over time is a powerful tool for documenting starting conditions and changes over time. Mark photo points (reference points) with steel pins or rebar so they can be found in the future. Document the location of photo points in your project log, and indicate the direction (compass heading) the photographer is facing from the photo point. See "For more information" (page 27) for additional resources on photo monitoring.

Other monitoring techniques

Most riparian monitoring will focus on project implementation: Did the planted trees survive, and are they healthy and vigorous? What problems require immediate attention? These questions can be addressed largely through periodic visual inspections.

More intensive monitoring techniques can provide quantitative information that is objective, repeatable, and statistically valid. These approaches are important for evaluating project effectiveness but are expensive and time consuming.

Regardless of the technique used, it's important to follow a consistent format for recording measurements and taking notes on project conditions.

Appendix D (page 26) lists examples of common monitoring questions, objectives, and techniques. See "For more information" (page 27) for additional resources on monitoring.

APPENDIX A. KEY RIPARIAN FUNCTIONS, SUPPORTING VEGETATIVE CONDITIONS, AND RIPARIAN BUFFER DESIGN CONSIDERATIONS

Riparian functions	**Vegetation conditions and** *functions supported*	**Riparian buffer design considerations**
Provide shade to keep water cool.	Shrubs and trees on the sunny side of the stream *Provide foliage to block sunlight.*	South and west sides of streams are most critical for shade plantings. Buffer width depends on stream size, slope, and orientation. This function can be attained relatively quickly.
Stabilize stream bank to prevent erosion.	Trees and shrubs on the stream bank and (on small streams) in the active channel *Roots hold soil, and stems slow water to reduce erosive force.*	A stream bend's inside bank requires a smaller buffer; its outside bank requires a larger buffer to account for channel migration. Vegetation within 25 feet of the channel provides most of the buffer's stabilization. This function gradually increases with development of surface cover and root structure.
Filter nutrients and sediments to maintain high-quality water.	Trees and shrubs at the upland edge of the riparian area *Vegetation cover slows and filters water flowing from adjacent uplands. Plant roots take up nutrients from the soil solution.*	Sediment filtration depends on slope, soil type, and other factors, such as the presence of drain tiles. A 50-foot buffer can provide substantial filtration of sediment from overland flow. Larger buffers may be needed to take up soluble nutrients and herbicides.
Modify stream flow; create resting cover pools or retain gravel to improve fish habitat.	Large trees falling into the stream *Woody debris lodged in the streambed slows and diverts water, causing gravel to accumulate. Water plunging over and circulating around woody debris forms and maintains pools.*	Most debris comes from trees directly adjacent to the stream channel. Landslides, floods, and debris flows can also provide significant debris, depending on landscape conditions beyond the riparian area.
Provide off-channel refuge.	Trees and shrubs along low areas of floodplain *Provides cover and slow-water areas for small fish overwintering in the lower Willamette system.*	Enhancement of existing sloughs and side channels may yield high-value benefits for fish habitat. This function can be quickly attained.
Provide nutrients to enrich aquatic system.	Vegetation overhanging the stream *Deposits leaves and twigs. Insects fall from vegetation into the water. Forms the basis of the aquatic food web in some streams.*	Most benefits come from vegetation hanging over or directly adjacent to the channel.
Provide habitat for nesting, roosting, foraging, and other terrestrial wildlife activity.	Dense areas of shrubs with an overstory including large live trees and dead trees (snags) *Shrubs and trees provide nesting and hiding cover and may provide corridors for wildlife passage.*	Buffer width depends on habitats and species of concern. Large buffers needed for wildlife corridors. Even with fast-growing species, development of these functions may be very slow.

APPENDIX B. PROMOTING NATURAL REGENERATION

Promoting natural regeneration (i.e., growth from seeds, roots, and stems) of trees and shrubs already on the site can help establish desired vegetation with less expense and effort than planting seedlings. This may be the core of a passive restoration strategy or a way to add diversity to a planting.

Other advantages of natural regeneration are that species are genetically adapted to local conditions and, especially with vegetative reproduction, set for rapid growth. Greater reliance on natural regeneration can also increase the cover of desirable riparian plants. However, natural regeneration alone generally is not a reliable way to meet establishment goals for species composition or an adequate number of trees and shrubs.

Conditions must be right for natural regeneration to occur:

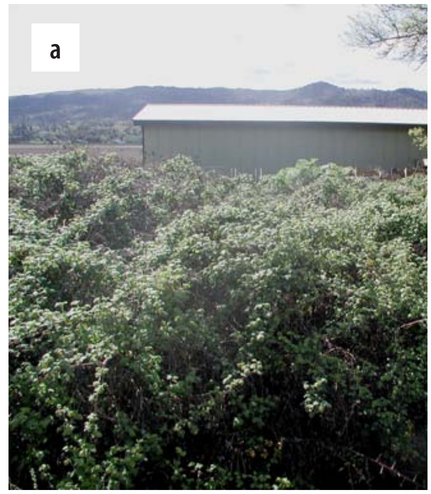
- Temporary freedom from vegetative competition
- Available sources of seed (of desired species)
- Abundant soil moisture

Conditions for natural regeneration are often most favorable close to the stream, where there is abundant soil moisture and where seasonal flooding prevents invasive species such as blackberry from establishing. Natural regeneration also frequently occurs in a pulse after a disturbance, such as a major flood that has cleared streamside vegetation and exposed or deposited fresh sand and gravel.

These conditions are ideal for germinating seeds of black cottonwood, willow, alder, and many other riparian species. They are not favorable for many conifers. Oregon ash, Oregon white oak, and hawthorn (both the native Douglas and invasive English) are likely to spread into wet meadow areas, even with some weed competition. Many riparian species also regenerate vegetatively, including resprouting from the root crown, root suckering, layering, and sprouting from stem fragments. This makes natural regeneration a useful but often unreliable source of recovery in years when seed production is low or matches poorly with natural disturbances, or when you want to develop woody cover farther from the active stream channel.

What can be done to enhance natural regeneration?

- Kill or cut back competing vegetation. Riparian plantings often contain more desired woody plants than first meet the eye. Locate and flag these plants before cutting.
- Stimulate root suckering, layering, and sprouting by cutting back competing vegetation twice per year. Black cottonwood (*Populus trichocarpa*) and sandbar willow (*Salix exigua*) sprout vigorously from underground shoot buds on lateral roots. A temporary reprieve from competition can help these species move rapidly into previously unoccupied areas (figure 22).
- Minimize cover of competing vegetation to stimulate germination and rapid early growth of seedlings of desirable species. A large amount of seed falls into riparian areas, but new plants can regenerate only under favorable conditions. It isn't important to eliminate competitors entirely, but you must reduce their cover to low levels while desirable species get established.
- Protect plants from livestock or other animal damage with fencing or individual tree protection.



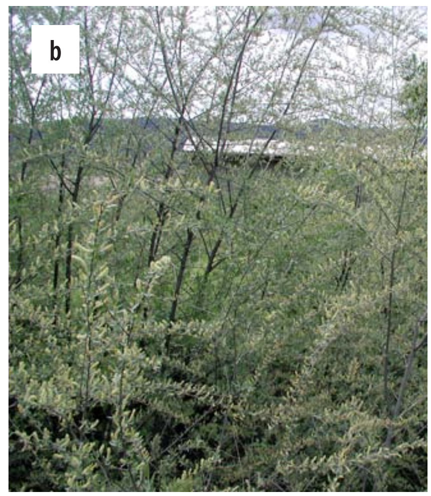


Figure 22. Two seasons after Himalayan blackberry was cut back on this site (a), sandbar willow has made a good recovery (b).

Photos by Max Bennett, © Oregon State University.

APPENDIX C. PROJECT DESIGN FEATURES AND CONSIDERATIONS

You considered functional goals (e.g., shade, bank stabilization, and habitat) when planning the project and selecting species. Optimize those functions with a thoughtful layout. Consult others; staff from soil and water conservation districts, watershed councils, and the Natural Resources Conservation Service generally have extensive experience with these practical design issues.

Buffer width

There is no one-size-fits-all buffer width. Wider buffers generally provide more benefits, but beyond a certain size, there may be relatively little increase in benefit for a relatively large increase in buffer width.

Optimal buffer widths vary depending on the desired riparian functions. For bank stability, relatively narrow buffers suffice. For wildlife habitat or travel corridors, wider buffers may be required (see Appendix A, page 22).

Consider a variable-width buffer. Good places for wider buffers are the outside bank of a stream bend (so the entire buffer isn't lost when the channel migrates) and on low terraces and low-gradient reaches (to enhance bank stability and off-channel habitat were flooding is more frequent).

On forestlands, the Oregon Forest Practice Act dictates minimum buffer widths. On agricultural lands, there are no specific buffer-width requirements; owners must comply with local water-quality management plans established under Oregon Senate Bill 1010. Contact your local soil and water conservation district or watershed council to learn about local water-quality management plans. City or county jurisdictions may have ordinances dictating buffer width.

Location

Some functions are more location-dependent than others. Vegetation on the south and west sides of the stream provides direct shade, which helps moderate water temperatures more than similar vegetation on the north side. Habitat functions (e.g., food and nesting) are not strongly related to position. Bank stability may be a key functional goal in areas subject to scour or stream meanders.

Access requirements

Provide access and adequate space between trees for any machinery to be used. Consider the benefits of rows for maintenance (e.g., mowing and spraying). Regular rows and adequate spacing between rows (5 to 10 feet) are needed for most small tractors and ATVs. Rows can look natural; they do not need to be straight lines. Sweeping curves work, too. Closer spacing and irregular tree distribution are OK if you will use smaller mowers, backpack sprayers, or hand tools.

Fencing and other livestock and wildlife controls

Standard woven wire and electric fencing are adequate for domestic livestock but require maintenance (figure 23). Carefully managed rotational livestock grazing can be compatible with riparian planting without fencing out the entire riparian area. However, cross-fencing to establish multiple pastures is key.

Deer and elk can jump easily over livestock fencing, so 8-foot or higher fencing is needed to protect plants from these animals. This can be prohibitively expensive; individual tree protectors often are used instead. An 18-inch-high chicken wire fence placed between the stream and planted stock keeps out most beaver and nutria.

File photo, © Oregon State University.

Figure 23. Riparian buffer installed next to a farm field. A stream is at left, outside the photo frame. In this case, livestock fencing (at right in photo) is essential to the success of the buffer planting.

Spacing and arrangement

The future diversity of your riparian woodland will depend not just on the species you select but also on the spacing and arrangement of your planting. Your design should reflect both short- and long-term goals.

Plant spacing

Appropriate plant spacing depends on several (sometimes competing) factors:

- Tree size, stand structure, and species composition needed to meet a project's functional goals
- Species characteristics (size, growth rate, form, and shade tolerance)
- Need for rapid establishment and occupancy by seedlings (increasing their ability to compete with weeds)
- How long and how well you can control competing weeds
- How quickly and to what degree seedlings compete with each other (affecting tree size, stand structure, and species composition)
- Your ability to thin in a timely manner

Mixed-species plantings

Mixed-species riparian plantings generally serve two purposes:

1. They provide "insurance" to cover uncertainties associated with seedling survival and species adaptation.
2. They establish a diverse plant community that will provide key habitat functions in the future.

The most common approach to developing a mixed-species planting is to use a random mix of species. This serves the first purpose but not necessarily the second.

Differing early growth rates affect how species interact and compete. Trees that establish and grow quickly often do so at the expense of neighboring plants, occupying space and consuming resources needed by each. Slower-growing trees fall behind and, depending on degree of crowding and their shade tolerance, may eventually die unless the planting is thinned. In a single-species stand, this competition affects the size and number of trees surviving but not the species present. In a mixed-species planting, competition favors one species over another and tends to shift the planting toward the faster-growing species. Diversity of the planting decreases as slower-growing species die, and any functional goals associated with these species won't be realized.

Research with a wide range of plants has demonstrated that this interaction is more pronounced the more dissimilar the growth rates among competing species. The interaction also is sensitive to plant spacing (density). The closer the spacing, the faster and more complete the displacement of the slower-growing species (figure 24a).

Strategies to allow slower-growing species (of a given shade tolerance) to survive longer include wider spacing (figure 24b) and clusters of individual species (figure 24c). Plants at the edge of a cluster of slow-growing species will be lost, but those inside are a safe distance from faster-growing competitors and can survive. Clustering is a good strategy to use when you want to plant close enough to cover planting losses and encourage rapid site capture but may be unsure of your future capacity for management (both weed control and thinning).

Consult with Oregon State University Forestry and Natural Resources Extension for more information about competition, stand development, and spacing and arrangement strategies for creating diverse riparian forests.

Research and demonstration of mixed-species plantings

Growing mixtures of species is challenging and requires good information about growth rates and other plant characteristics. Unfortunately, such information isn't available for many restoration species growing in riparian conditions. Ecological principals and established forestry practices can provide useful guidance, but demonstration and applied research are desperately needed.

A network of simple plots across a range of Willamette Valley soils would provide valuable information for current and future restoration project managers. Contact the authors if your watershed council or soil and water conservation district would be interested in contributing to this effort.

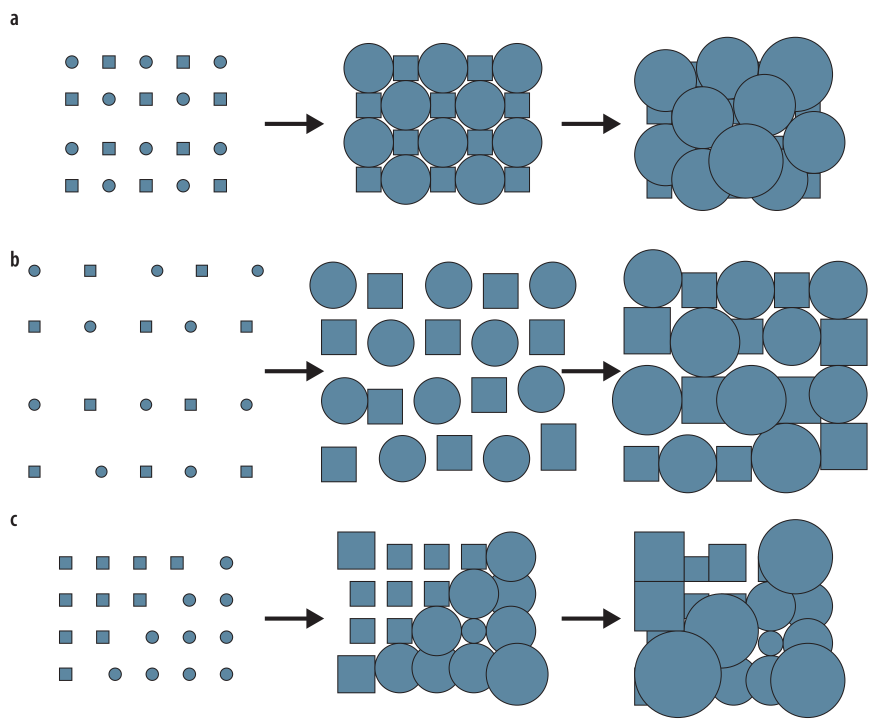


Figure 24. Mixed-species plantings have many advantages, but how the species are mixed at planting can lead to different outcomes as the trees and shrubs grow: (a) two species with different growth rates intermixed at a close spacing, (b) two species intermixed at wider spacing, and (c) two species clustered.

APPENDIX D. SAMPLE MONITORING QUESTIONS, OBJECTIVES, AND TECHNIQUES

Monitoring question	Objective	Technique
How many trees, stream frontage, or area planted? Where?	Document the project for project managers, funders, etc.	Include this information in your project documentation and monitoring plan.
Are the planted trees threatened by weeds or animal damage?	Assess immediate threats to tree vigor and survival and need for action.	Visual inspection of planting area. Timing: The spring after planting is most critical. Inspect at least once per season.
Did the planted trees survive?	Determine overall success of the planting. Is replanting necessary (if below some threshold)?	Visual inspection or intensive measurement. Walk the site to get a general sense of tree survival, or tally every tree or a representative sample of trees to determine survival rate. Flagged tree locations can be helpful. Timing: Inspect at the end of the growing season. The first growing season is an important benchmark; most mortality occurs in the first year.
Are the planted trees vigorous?	Evaluate success of the planting. Vigor is one criterion.	Visual inspection or intensive measurement. Indicators of vigor include plant size, leaf size, bud size, needle length, leaf length, and foliage color. Timing: Inspect during the growing season.
How fast are trees growing?	Determine overall success of the planting. Also, determine how growth varies by planting site, species, treatment, and other variables.	Visual inspection or intensive measurement. Height is less sensitive than diameter to effects of vegetative competition. Thus, differences in diameter often are used to evaluate treatment effects, such as different site preparation methods.
Are trees "free to grow"?	"Free to grow" is an important benchmark for project success. At this stage, trees should be able to dominate the site without further intervention.	Free-to-grow trees are vigorous, not threatened by competing vegetation, and poised for further growth and site dominance without additional intervention. Determining whether a tree is free to grow is somewhat subjective. Timing: Reaching free-to-grow stage is site specific. Upland conifers plantings usually require 4 to 6 years.
Are trees doing better in one area than another? Areas may differ ecologically (e.g., soils and drainage) or in treatments (e.g., site preparation).	Determine success of each section of the planting. Also, learn about factors affecting plants on the site and what might be done differently next time.	Visual inspection or intensive measurement. Compare tree survival, vigor, and growth (e.g., height, diameter, and stem volume).
What are the major reasons trees died?	Learn about factors affecting plants on the site and what might be done differently next time.	Visual inspection or intensive measurement. Note any evidence of trees dying from overtopping/encroachment of competing vegetation, lack of water, lack of nutrients, animal damage, etc.
Is the riparian condition trend positive (e.g., is cover of desirable vegetation increasing)?	Determine whether riparian goals are being met.	Photo monitoring or intensive measurement.
Did the project increase shade to the stream?	Determine whether riparian goals are being met.	Photo monitoring may show increases in stream cover. Intensive measurement (e.g., with a solar pathfinder or fish-eye lens) is needed to quantify increases in shade.
Did the project reduce nitrate input to streams from adjacent farmlands?	Determine whether riparian goals are being met.	Intensive measurement.

FOR MORE INFORMATION

The following publications are available through the Oregon State University Extension Service Catalog (*http://extension.oregonstate.edu/catalog*):

Introduction to Conifer Release (EC 1388)

Managing Himalayan Blackberry in Western Oregon Riparian Areas (EM 8894)

Pacific Northwest's Least Wanted List: Invasive Weed Identification and Management (EC 1563)

Pacific Northwest Weed Management Handbook (WEED): *http://pnwhandbooks.org/weed*

Seedling Care and Handling (EC 1095)

Selecting and Buying Quality Seedlings (EC 1196)

Selecting Native Plant Materials for Restoration Projects (EM 8885)

Site Preparation: An Introduction for the Woodland Owner (EC 1188)

The Care and Planting of Tree Seedlings on Your Woodland (EC 1504)

Tree Buffers along Streams on Western Oregon Farmland (EM 8895)

ADDITIONAL RESOURCES

To locate the watershed council in your area, visit *http://www.oregon.gov/OWEB/WSHEDS/wsheds_councils_list.shtml*

Anderson, M., and G. Graziano. 2002. *Statewide Survey of OWEB Riparian and Stream Enhancement Projects*. Salem, OR: Oregon Watershed Enhancement Board.

Crowder, W., and W. Edelen. 1996. *Riparian Moisture Zones: Planting Locations of Woody and Herbaceous Species*. Technical Note 31. Pullman, WA: USDA-NRCS Pullman Plant Materials Center.

Falk, D.A., M.A. Palmer, and J.B. Zelder (eds.). 2006. F*oundations of Restoration Ecology*. Washington, D.C.: Island Press.

Fisher, R.A. 2004. *Using Soil Amendments to Improve Riparian Plant Survival in Arid and Semi-arid Landscapes*. Vicksburg, MS: USAE Research and Development Center, Environmental Laboratory.

Hall, F.C. 2002. *Photo Point Monitoring Handbook, Part A—Field Procedures*. General Technical Report PNW-GTR-526. Portland, OR: USDA Forest Service, Pacific Northwest Research Station.

Oregon Department of Forestry. *Sources of Native Forest Nursery Seedlings* (annual catalog with seed zone maps). *http://www.oregon.gov/ODF/privateforests/docs/ForestNurserySeedlingSources.pdf*

Oregon Watershed Enhancement Board. 2004. *Oregon Riparian Assessment Framework*. *http://www.oregon.gov/OWEB/docs/pubs/OR_RiparianAssessFramework.pdf*

Prichard, D. 1995. *Process for Assessing Proper Functioning Condition*. Technical Reference 1737-9. Denver, CO: U.S. Department of the Interior, Bureau of Land Management.

Watershed Professionals Network. 1999. *Oregon Watershed Assessment Manual*. (Developed for the Governor's Watershed Enhancement Board). *http://www.oregon.gov/OWEB/docs/pubs/OR_wsassess_manuals.shtml*

Winward, A.H. 2000. *Monitoring the Vegetation Resources in Riparian Areas*. General Technical Report RMRS-GTR-47. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station.

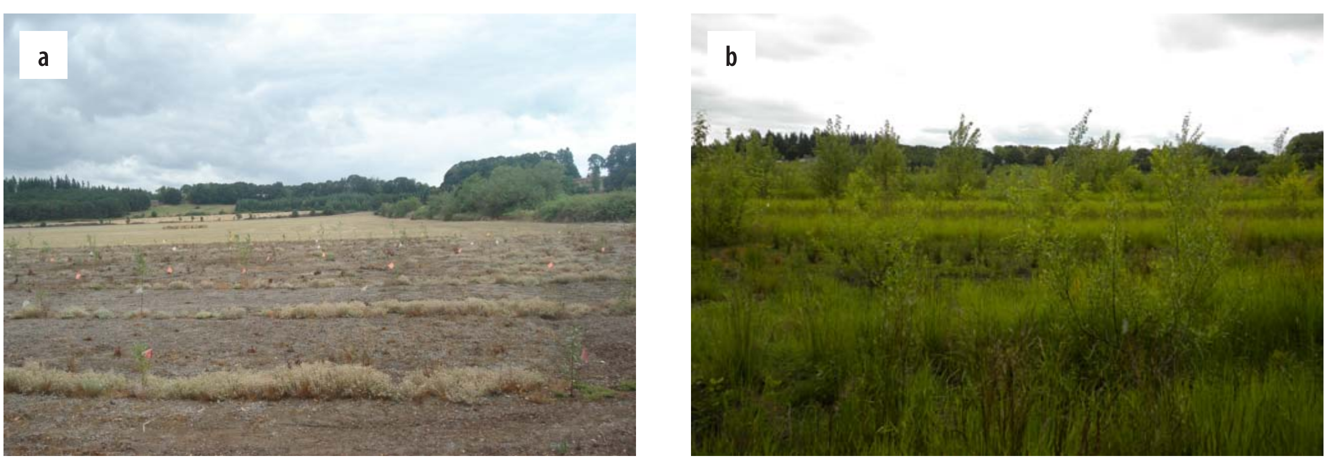


Figure 25. A successful riparian planting along Evergreen Creek, Benton County, Oregon, in the year of planting (a) and after three growing seasons (b). Trees and shrubs were planted in meandering rows at about 525 plants per acre. Note that initial broadcast weed control (a) has been replaced with swaths of native grasses between herbicide strips in tree/shrub rows (b).

Photos by Ray Fiori, Oregon Wetlands LLC.

Use herbicides safely!

- Wear protective clothing and safety devices as recommended on the label. Bathe or shower after each use.
- Read the herbicide label—even if you've used the pesticide before. Follow closely the instructions on the label (and any other directions you have).
- Be cautious when you apply herbicides. Know your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from pesticide use.

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